

E L E M E N T S
O F
N A T U R A L H I S T O R Y,
A N D O F
C H E M I S T R Y:

BEING THE SECOND EDITION OF
THE ELEMENTARY LECTURES ON
THOSE SCIENCES,

FIRST PUBLISHED IN 1782,

A N D N O W

GREATLY ENLARGED AND IMPROVED,

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WITH OCCASIONAL NOTES, AND AN HISTORICAL
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SUPPLEMENT

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ELEMENTS

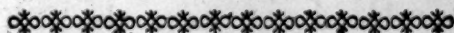
E L E M E N T S

O F

NATURAL HISTORY

A N D O F

C H E M I S T R Y.



Continuation of the Third Section of
Mineralogy, or the History of Com-
bustible Bodies.

C H A P. IX.

Of Bismuth.

BISMUTH, or tin glass, is a semi-metal, of a yellowish white, very ponderous, and disposed in large plates. It scarcely yields at all to the strokes of the hammer without breaking into small brilliant pieces, and may even be beat into powder. By immersion in water, it loses about $\frac{1}{10}$ of its weight. It is suscep-
Vol. III. A tible

tible of crystallization, in the form of polygonal prisms, which are disposed in quadrangular solids, perfectly similar to those of marine salt. It has scarcely any smell or taste.

Bismuth is often found native. It is known by its yellowish brilliant colour; its softness, or yielding to the knife; its laminated texture when broken; and, more especially, by its very great fusibility. It is ordinarily crystallized in triangular laminæ, which are placed one over the other slantwise. I am in possession of specimens of this semi-metal, in the form of very regular octahedrons; its gangue is commonly quartzose. It is found at Scala, in Neritia, in Dalecarlia, and at Schneeberg in Germany.

Many modern mineralogists doubt the existence of the arsenical ore of bismuth. Some of them however affirm that this ore is chatoyant, and commonly disposed in small glittering laminæ of a bright grey colour. It is likewise, according to these authors, almost always mixed with native bismuth and cobalt, whose reddish efflorescence is observable on the surface of the specimens.

The sulphureous ore of bismuth is of a whitish grey, inclining to blue, with pointed facets, or acute prisms; it has the brilliancy and colour of lead ore, or galena, and almost always exhibits square facets; but it
is

is never found in fragments truly cubical. It may be cut with a knife. It is very rare, and is found at Bastnas in Sweden, and at Schneeberg in Saxony.

Cronstedt likewise speaks of a martial ore of bismuth, which he says is found in large cuneiform scales at Kongsberg in Norway.

Lastly, bismuth is sometimes met with in the calciform state. This is in the form of a granulated efflorescence, of a greenish yellow, and never of a red colour, on the surface of ores of bismuth. Mr. Kirwan thinks that the calx of bismuth is united with the cretaceous acid. Some mineralogists affirm, that the native vitriol of bismuth is mixed with this calx.

To make an assay of the ore of bismuth, it is usually reckoned sufficient to expose it to a low degree of heat in a crucible, together with a certain quantity of reducing flux. As bismuth is volatile, the fusion should be made as quickly as possible; it would indeed be better to make this assay in close vessels, as Cramer recommended.

The smelting of bismuth in the large way, is not attended with more difficulty. A cavity is made in the earth, which is covered with billets of wood placed one on the other; the wood is set on fire, and the ore being broken small, is thrown in it. The bismuth melts, and runs into the cavity, where it takes an orbicular form. In other places

the trunk of a pine tree, hollowed into the form of a gutter, is placed in the earth in an inclined position, and wood laid over it; the bismuth is thrown on this combustible matter after it is set on fire: the semi-metal melts, falls into the channel, which conducts it into a cavity made in the earth, over which the extremity of the trunk is placed. The bismuth, thus obtained, is poured into iron moulds.

Bismuth is scarcely at all altered by the contact of light. It is extremely fusible, and melts long before the red heat commences. In closed vessels it sublimes without alteration; if it be permitted to cool slowly, it crystallizes in Greek volutes; it crystallizes the most easily of any metallic substance. Mr. Brongniart is the first chemist, who perfectly succeeded in producing this crystallization.

If bismuth be kept in fusion with contact of air, its surface becomes covered with a pellicle, which changes into an earth of a greenish grey, or brown, named calx of bismuth. Nineteen drachms of bismuth calcined in a capsule of glass, afforded Mr. Baumé twenty drachms thirty-four grains of calx. Bismuth heated to redness, burns with a small blue flame, scarcely sensible. Its calx evaporates in the form of a yellowish smoke, which condenses on the surface of cold bodies, into a powder of the same colour,

colour, called flowers of bismuth. This powder owes its volatilization only to the rapidity with which the bismuth burns; for if it be exposed alone to fire, it melts into a greenish glass, without subliming. Geoffroy the younger observed, that the flowers of bismuth, which rise the last, are of a beautiful yellow, resembling orpiment.

The grey or brown calx, the yellow flowers, and the glass, are nothing more than combinations of this semi-metal, with the base of vital air, or the oxigynous principle. They are not reducible without addition, because the adhesion between the two principles, which compose them, is very considerable; but inflammable gas, and all organic combustible matters, are capable of decomposing them, and restoring their metallic state, by seizing the oxigynous principle with which these bodies have more affinity than bismuth.

Mr. D'Arcet having exposed bismuth in a ball of unbaked porcelain, to the heat of the furnace in which that substance is usually baked, part of the semi-metal flowed out through a crack; the portion, which remained in the vessel, formed a glass of a dirty violet colour, while the bismuth, melted in communication with the external air, was yellowish. From this fact, and many others of a like nature, it appears, that

glasses made with or without the contact of air, are different from each other.

Bismuth becomes tarnished a little by exposure to the air, whitish rust being formed on its surface. It is not attacked by water, neither does it combine with earths; but its calx unites with all earthy matters, and facilitates their fusion: it gives a greenish yellow tinge to glasses into which it enters.

The action of the salino-terrestrial substances, and alkalis on this semi-metal, are not yet known.

Boiling oil of vitriol acts on bismuth, partly decomposing it, and sulphureous gas exhales. The mass remaining in the vessel after the decomposition of a part of the acid is white; that portion which is in the saline state may be separated by means of water, from the other portion which is calcined, and does not contain any acid: the lixivium, by evaporation, affords a vitriol of bismuth, in small deliquescent needles. This salt is decomposable by fire, by the salino-terrestrial substances, by alkalis, and even by water alone, in large quantities.

The nitrous acid dissolves bismuth with an astonishing rapidity; or rather this semi-metal decomposes the acid, and very quickly takes from it the oxigenous principle; the mixture becomes very strongly heated, and emits dense red vapours. If the combination

ination be made in the pneumato-chemical apparatus, a large quantity of nitrous gas is obtained; and this process is one of the readiest and most convenient for procuring this gas. During the solution, a black powder is precipitated, which Lemery supposed to be bitumen, and Pot considered as calcined bismuth; Mr. Baumé suspected it to be sulphur.

The nitre solution of bismuth is without colour, and when it is much saturated, it affords crystals without evaporation. Evaporation, and cooling, afford a nitre of bismuth; concerning the form of which chemists differ. Mr. Baumé affirms, that this salt is disposed in large needles, pointed at one end. Mr. Sage asserts, that the crystals are tetrahedral prisms, a little flattened and terminated by two obtuse trihedral pyramids, whose planes make one rhombus and two trapeziums. By a slow evaporation, I have obtained flattened rhomboids, very large, and perfectly similar to the calcareous spar of Iceland.

The nitre of bismuth detonates feebly, and with reddish scintillations, after which it melts and swells up, leaving a calx of a greenish yellow, not reducible without addition. This salt exposed to air, loses its transparency, at the same time that the water of crystallization is dissipated. If water be added, instead of dissolving it, the fluid

becomes white, milky, and a calx of bismuth is precipitated.

The same thing happens, if the nitrous solution of bismuth be poured into water; the greatest part of the calx of this semi-metal being precipitated under the form of a white powder, called magistery of bismuth. One hundred grains of this metal, dissolved in the nitrous acid, afford one hundred and thirteen grains of magistery, by reason of the oxigenous principle with which it combines. A large quantity of water must be used, if the precipitate be desired very white and fine. It is used as a pigment for rendering the skin white, but it has the inconvenience of becoming black, when in contact with odoriferous or combustible matters. This property is more evident in this, than in most of the metallic calces. Though nitre of bismuth be in a great measure decomposed by water, a portion nevertheless remains dissolved, which cannot be precipitated, but by lime or alkalis. The character of being precipitated by water, is common to all the solutions of bismuth.

The muriatic acid acts with difficulty on this semi-metal. It is necessary that the acid should be very concentrated, and be kept in digestion on the bismuth for a long time; the solution succeeds still better, when a large quantity of marine acid is distilled

tilled from the metal. The mixture has an hepatic smell; the residue is to be washed with water, which becomes charged with a portion of the metallic calx united to the acid. The muriate of bismuth crystallizes with difficulty; it may be sublimed into a kind of butter; it strongly attracts the humidity of the air; and lastly, water decomposes it, and precipitates it in the form of a white calx.

The action of the other mineral acids on bismuth is not known.

Bismuth is calcined by nitre, but without any sensible detonation; this semi-metal does not decompose sal ammoniac, but its calx completely separates the volatile alkali from this salt. In this experiment a large quantity of alkaline gas is obtained, and the residue is a combination of the metallic calx, with the muriatic acid. If bismuth do not act on the sal-ammoniac, in consequence of the small degree of action, which the muriatic acid has for this semi-metal; the property its calx possesses of decomposing this salt, is very remarkable, and proves that it in some measure resembles saline substances.*

* The decomposition of sal ammoniac, by the calx of bismuth, agrees with the general tenor of facts, which shew, that the calces of metals are more strongly acted on by the muriatic acid, than the metals themselves: the cause of this need not be here insisted on. T.

Inflammable

Inflammable gas alters the colour of bismuth, and gives it a violet tinge.

Sulphur combines with this semi-metal by fusion, and produces a sort of grey mineral, of a blueish and brilliant appearance, which crystallizes in beautiful tetrahedral needles, similar in colour and appearance to the finest specimens of antimony.

The action of arsenic on bismuth is not well known. This semi-metal does not unite with cobalt, which remains separate from it in the smelting.

Bismuth is employed by the pewterers, to communicate hardness to tin. It may be substituted instead of lead, in the art of cupelling the perfect metals, because, like that metal, it has the property of flowing into a glass, which is absorbed by the cupels. Geoffroy the younger has observed, and recorded many circumstances in which this semi-metal resembles lead. The effects of bismuth on the animal economy can only be conjectured; but there is reason to think that its use, like that of lead, would be dangerous; and there are some instances of bad effects arising from the external use of this semi-metal. We have already observed, that the calx of bismuth is used as a pigment for the skin, and that strong smelling matters alter its colour; such smells as are fetid, more particularly produce this effect. The vicinity of slaughter-

ter-

ter-houses, of common-sewers, of necessary-houses, and almost every other strong smell, has that effect on this calx, and cause its colour to become more or less black. The vapour of liver of sulphur, or the smell of eggs, produce this effect very quickly. A very common experiment in natural philosophy shews this property in a striking manner. If characters be written with a solution of bismuth, on the first page of a book of fifty leaves, and the last page be impregnated with a small quantity of the liquid liver of sulphur; a short time afterwards, the hepatic vapour carried by the air, which circulates between all the leaves, arrives at the other extremity of the book, and converts the colourless characters marked on the first page into a deep brown. It is affirmed, that the hepatic gas passes through the paper; but Mr. Monge has proved, that it is the air which carries it in this manner, from one leaf to another, since the effect does not take place, when the leaves are glued together.

C H A P. X.

Concerning Nickel.

NICKEL was considered by Cronstedt, as a peculiar semi-metal, when he first made it known in the year 1751, and 1754, in

in the acts of the Academy of Stockholm. This semi-metal, according to him, is of a white brilliant colour, tending to red; especially at the external surface. It is very brittle, and in its fracture appears to be composed of facets, which distinguish it from cobalt. Mr. Arvidson, who, together with Bergman, has published a thesis on the properties of nickel, which is translated, and inserted in Rosier's Journal, for October, 1776, observes, that nickel obtained by the roasting and fusion of its ores, as Cronstedt directs, is far from being in a state of purity, and that it contains sulphur, arsenic, cobalt, and iron. As Bergman has succeeded by a great number of ingenious processes, to deprive it of most of these foreign matters, and to obtain nickel different from that of Cronstedt, in many of its properties, we shall follow his authority, after having first spoken of its ores.*

Nickel is found united to sulphur and arsenic. Its ores have a coppery red colour, and are almost always covered with a greenish grey efflorescence. The Germans call it kupfer-nickel, or false copper. This mineral is very common at Freyberg, in Saxony, where it is often mixed with the grey ore of cobalt; but its red colour, and

* This Essay is printed in the second volume of the English translation of Bergman's Essays. T.

its greenish efflorescence, distinguish it from that ore, which is grey or black, and has a red efflorescence. It is often crystallized in cubes. Wallerius distinguishes the kupfer-nickel, by the name of cobalt ore, of a coppery red; he thinks it to be a compound of cobalt, iron and arsenic. Linnæus considered it as copper mineralized by arsenic. Romé de Lisle has arranged it, with Wallerius, among the ores of cobalt, and like him, thinks that it is a compound. Mr. Sage having treated this ore with sal ammoniac, obtained iron, copper, and cobalt; he thinks that it is composed of these three metallic matters, together with arsenic. It likewise contains a small proportion of gold, according to this chemist. It is proper to observe, these results do not agree with those of Bergman; he is said to have operated on the kupfer-nickel of Biber, in Hesse, and of Allemont in Dauphiny.

Cronstedt assures us, that the metallic matter called speiss by the Germans, which is collected in the crucibles used in the melting of smalt, affords nickel. Mr. Monnet thinks that the speiss, of the manufacture of Gengenback, 14 leagues from Strasburg, is true nickel; and as the ore of cobalt made use of in that place to make smalt, is very pure, he concludes that nickel is necessarily a product of cobalt itself, as we shall presently see. But Mr. Baumé has obtained

obtained nickel from almost all the ores of cobalt by means of sulphur; it therefore seems that the ore of cobalt, which is wrought at Gengenback, contains nickel not distinguishable by the eye, on account of the intimate union of these two metallic matters.

To obtain nickel from the ore, it is slowly roasted, in order to drive off a portion of the sulphur and arsenic it contains. It is by this means converted into a greenish calx. The greener it is, the greater the quantity of nickel it contains, according to Bergman and Arvidson. It is afterwards melted with three parts of black flux and marine salt, and a regulus is by that means obtained, such as Cronstedt speaks of, but which is far from being pure nickel. Its scorix are brown or blue. Many chemists, since the experiments of Arvidson, still continue to think that this metallic substance is a natural alloy of iron, cobalt, and arsenic; as to copper, there is no chemist but Mr. Sage, who affirms, that he has obtained it from kupfer-nickel. Mr. Monnet thinks that nickel is cobalt, deprived of iron and arsenic. In proportion as we shall proceed in the examination of the properties of this semi-metal, we shall perceive the causes of these different opinions having been adopted. We think with Bergman, that the extreme difficulty of obtaining nickel in a state of purity,

purity, is the circumstance which has deceived the generality of chemists; and this truth is fully proved in the dissertation of Mr. Arvidson, already quoted. As it is certain that this metallic substance has very peculiar properties, however pure it may be made; and that no means of separating it by analysis into different metallic substances, nor of recomposing it by any mixture, have been yet discovered; it ought to be regarded as a peculiar semi-metal, till further experiments shall convince us to the contrary.

The semi-metal which affords, by simple fusion, kupfer-nickel, is of a reddish white, very brittle, and of a plated texture. It contains much arsenic, cobalt, and iron. Mr. Arvidson subjected it to six calcinations, each for the space of between 6 and 14 hours, and reduced the regulus after each calcination. During the calcination, he observed, that vapours of arsenic, and white vapours which have not the smell of this semi-metal, were driven off: the powder of charcoal added in these operations, facilitated the volatilization of the arsenic. The nickel, whose weight was greatly diminished by these six calcinations, still had an arsenical smell, and continued to be attracted by the magnet. It was then fused six times with lime and borax, and calcined a seventh time, with the addition of charcoal, till it no longer sent forth arsenical fumes: this
calx

calx was ferruginous, and striped with green. When reduced, it afforded martial ochre, and a button still obedient to the magnet. These experiments have always succeeded in the same manner, with many specimens of nickel from different countries. Treatment with sulphur, and liver of sulphur, detonation with nitre, solution in the nitrous acid, and in the volatile alkali, made by Mr. Arvidson, never deprived nickel of all its iron. From these experiments he concluded, that it is impossible to purify this semi-metal accurately; that the sulphur is not separated but by repeated calcinations; that the arsenic adheres still more strongly; that it may be drawn off by the assistance of powder of charcoal, and of nitre; that cobalt is still more intimately combined with this semi-metal, since the nitre shews its presence, though no other indications were before perceived; and that it is impossible to deprive it of all the iron it contains, because when the nickel has been treated in all these various manners, it is sometimes more strongly attracted by the magnet than before. Mr. Arvidson thinks, from these circumstances, that this substance is nothing else but iron in a peculiar state, and he has drawn up a comparative view of many of the properties of cobalt, of loadstone, and of nickel; from which he considers these three
metallic

metallic matters as iron differently modified. But as the principal property of nickel, which has led Mr. Arvidson to this conclusion, is its magnetism; may we not conclude that these two metallic substances, so different in all their other properties, are not to be confounded together on this account? for it has not been proved that magnetism is peculiar to iron, or that it may not exist in many other metallic substances. I think therefore, that notwithstanding the property of being attracted by the magnet which nickel possesses, it ought to be considered, when purified by the processes of Mr. Arvidson, as a peculiar semi-metal; since it cannot be extracted either from other metallic substances, nor can be perfectly imitated by any mixture; and lastly, because it possesses properties common to no other metal, as we shall proceed to shew. Mr. Kirwan has entirely adopted this opinion in his mineralogy.

Its texture is not plated, as Cronstedt asserted, but granulated, as its fracture shews. It is nine times heavier than water. It is not brittle, but on the contrary, sufficiently ductile, to make it a question with Bergman, whether he should rank it among the metals or semi-metals. It is nearly as difficult to melt as forged iron, is extremely fixed in the fire, and becomes calcined when

heated with access of air, affording a calx of a green, which is deeper in proportion to its purity: it is not known whether this calx is fusible into glass. The fluxes and combustible matters commonly used in reducing the metals, produce their effect with this. The action of air and water on nickel are not known; its calx, when melted with matters proper to form glass, gives them a hyacinthine colour, more or less red. The action of lime, magnesia, and the three pure alkalies, on nickel, are still unknown.

Mr. Sage affirms, that when four parts of oil of vitriol are distilled from one part of the regulus of kupfer-nickel, in powder, the sulphureous acid passes over: the residue is greyish, and being dissolved in distilled water, produces the most beautiful green colour. The crystals obtained from this solution are foliated, and of the colour of an emerald. According to Mr. Arvidson, the vitriolic acid forms a green salt, in decahedral crystals, with the calx of nickel. These consist of two quadrangular pyramids, united together and truncated near their base.

This calx is easily soluble in the nitrous acid, and crystallizes in rhombic cubes. According to Mr. Sage, all the other solutions of nickel, or its calx, either in the muriatic acid, or in vegetable acids, are more or less green. Fixed alkalis precipitate

precipitate it of a greenish white colour, and re-dissolve it, at which period the liquid becomes yellowish. The volatile alkali, poured into a solution of nickel, produces a beautiful blue colour; this salt presents the same phenomena, when mixed with the precipitates of this semi-metal, by fixed alkalis. As the solutions of copper exhibit the same colour with volatile alkali, which is esteemed a very proper test of the presence of copper, it has been thought that nickel contains this metal. Cronstedt, however, tried in vain all the known methods of extracting copper from the solution of nickel, tinged blue by the volatile alkali. This salt, besides, does not immediately dissolve nickel, as it does copper. It is therefore proved, as Bergman thinks, that the property of turning green belongs to nickel itself, and is not owing to the presence of copper. This chemist did not observe any certain signs of the solution of nickel, by the cretaceous acid, in an experiment where he kept this metal for eight days in water, impregnated with that acid.

Nickel detonates with nitre; this detonation afforded Mr. Arvidson a method of discovering the presence of cobalt, which no other proof had rendered sensible. Nitre has likewise the property of augmenting the intensity of the hyacinthine colour, communicated by calx of nickel to glasses, and

of causing it to re-appear after it has been dissipated by heat, as frequently happens with this calx in glass, and is common to it with the semi-metal we shall next proceed to examine.

The calx of nickel fused with borax, likewise gives it an hyacinthine colour.

It partly decomposes sal-ammoniac. The martial flowers obtained by Mr. Sage, in this experiment, arose from his not having employed a regulus as pure as that of Mr. Arvidson; for this last chemist assures us, that the flowers he obtained by solution were white, and gave no indication of the presence of iron, by the test of nut galls: a small quantity of volatile alkali, and muriatic acid, passes into the receiver; the residue, when reduced, affords nickel partly deprived of its magnetism.

The action of inflammable gas on nickel is not yet known.

This semi-metal combines readily by fusion with sulphur, and then forms a kind of hard mineral, of a yellow colour, with small brilliant plates. When strongly heated in contact with air, it deflagrates, and emits very luminous sparks, similar to those afforded by iron when forged. Cronstedt, who first made this experiment, did not pursue it; he observed only, that the phenomenon does not take place, if the contact

contact of air be prevented, by covering the metal with glass in fusion. The same chemist acquaints us, that this semi-metal is soluble in liver of sulphur, and forms a compound, resembling the ores of copper. The sulphur cannot be separated from nickel, but by repeated fusions and calcinations.

Nickel combines with arsenic, to which it has a strong attraction. Mr. Monnet (who at first, after Cronstedt, considered nickel as a peculiar semi-metal) having observed that it forms a blue glass when united to arsenic, similar to that which cobalt affords, adopted the opinion that nickel is nothing else but cobalt deprived of arsenic and iron. Mr. Monnet therefore considers cobalt, as well as nickel, as metallic mixtures. Bergman thinks, that if a blue glass be obtained, by the addition of arsenic to nickel, no other consequence ought to be deduced, than that it is caused by the cobalt, which it is known to contain, and whose properties are hidden by the latter, till it is calcined and separated from the nickel by means of arsenic; at which time its properties, more especially that of flowing into a glass, of a blue tinge, shew themselves. We have already observed, that nickel cannot be entirely separated from arsenic, but by repeated calcinations, with the addition of charcoal in powder. Nickel unites still more intimately

to cobalt than to arsenic, so that they cannot be separated without the greatest difficulty. Cobalt may exist in this combination, without shewing any indications of its principal properties. Nitre, borax, and arsenic, are the only substances by which its presence can be exhibited in fusion.

Cronstedt affirms, that nickel forms with bismuth a brittle and scaly regulus; the solution in the nitrous acid separates these two semi-metallic substances imperfectly, by virtue of the property which nitre of bismuth possesses of being decomposed by water. No use has yet been made of nickel.

C H A P. XI.

Concerning Manganese.

MANGANESE, a grey dark coloured mineral, which soils the fingers, and is employed in glass-houses in different proportions, either to colour, or to take away colour from glass, has been long known by the name of black magnesia, or manganese. Workmen have called it the sope of glass, from its property of rendering it colourless. Many naturalists, judging by its colour, and the martial earth with which its surface is often covered, have taken it for a meagre ore of iron. Pott and Cronstedt,
after

after an exact analysis, did not consider it as a ferruginous matter. The latter affirmed, that it contains a small proportion of tin. Mr. Sage reckons it among the ores of zink, and thinks that it is formed by the combination of that semi-metal and cobalt with the muriatic acid; he adds, from his own trials, that it sometimes contains iron or lead.

The weight of manganese, its property of tinging glass, and of affording a whitish precipitate when the phlogisticated alkali is poured into its solutions, caused Bergman to suspect, as he acquaints us in the last paragraph of his dissertation on the elective affinities, that this mineral contains a peculiar metallic substance. His suspicion has been fully confirmed by one of his disciples Mr. Gahn, doctor in medicine at Stockholm, to whom, together with Scheele, we are indebted for the discovery of the phosphoric acid in bones. This physician is the first who obtained a regulus of manganese, probably by treating it with reducing flux. The degree of fire necessary for this operation, is, doubtless, very great; for I have been a witness to the attempts of Mr. Brongniart, an experienced chemist, who tried in vain to reduce it in a furnace, which was capable of producing an excessive degree of heat. I have been assured, that the reduction has been successfully performed at Pa-

ris by employing the flux of Mr. De Morveau, with which this chemist obtained iron in a very well formed button: but I think that Mr. De la Peyrouse is much in the right in his opinion, that fluxes are pernicious in this operation. I have attempted the reduction in an excellent melting furnace, constructed in the laboratory of the Veterinarian school at Alfort. I have not yet obtained a perfect button, but I have obtained a considerable quantity of metallic globules, two or three lines in diameter. On several occasions, when I have employed fixt alkalis and borax, no metal was reduced. In my trials, each small metallic globule of manganese was incrustated with glass, or a vitreous frit of a deep colour. Manganese ought to be considered as a peculiar semi-metal, because its analysis has not yet been made, and it is found to possess properties common to no other metallic substance. Mr. De Morveau, in his translation of Bergman, calls the regulus, manganese, and proposes to call those substances from which it is obtained, and in which it exists in a californ state, ores of manganese. The properties of this semi-metal have been greatly elucidated by the labours of Bergman, Scheele, Gahn, Rinman, Engestrom, Ilseman and Peyrouse. It is from the labours of these chemists, as well as from my own particular experiments, that I shall borrow the following

ing

ing account of this substance; first observing, that the difficulty of reducing the ores of this semi-metal, is the cause why we are much better acquainted with the properties of its calces, than with those of the metallic substance itself. Mr. Scheele, one of the first chemists of the present age, does not appear to have succeeded in reducing it, since he no where speaks of the properties it possesses in the metallic state.

The ores of manganese are known by their grey, brown, or black colour, more or less brilliant, and likewise by their external appearance: they may be distinguished into a considerable number of varieties.

Variety

1. Ore of manganese crystallized in rhomboidal prisms, striated in the direction of their length, and separated from each other.
2. Crystallized ore of manganese, whose prisms are disposed in bundles, or aggregates.
3. Crystallized ore of manganese, in small needles, disposed in the form of stars.
4. Efflorescent ore of manganese, black and friable; it soils the fingers like foot.
5. Velvet ore of manganese; these are very small needles, which falling in-
to

to efflorescence, have a beautiful dead black colour, resembling velvet.

6. Compact and amorphous ore of manganese, of a black grey, often with cavities, and very heavy; it soils the fingers, and is sometimes found in brilliant needles. The Perigord stone belongs to this variety.
7. Spathose manganese, found in the iron mines of Klapperud, at Fresco in Dalecarlia, and described by Mr. Rimman.
8. Native manganese, in metallic globules, found at Sem, in the county of Foix, by Mr. De la Peyrouse, and described by him, together with many varieties of the ores of manganese, found at the same place, in Rozier's Journal for January 1780.

Mr. Scheele has discovered the calx of manganese in the ashes of vegetables, and attributes the green and blue colour, which fixt alkali often takes in calcination, to its presence. The green colour of the alkali of tartar treated with lime, and the rose colour which I have often observed in its combination with acids, arises, no doubt, from this metallic calx.

Manganese, extracted from its ore, is of a brilliant white; when broken its texture appears granulated like that of cobalt. It is hard, and breaks, after being in a small degree

gree flattened by the hammer. Its infusibility is greater than that of iron, which at first caused Bergman to conjecture, that it has some affinity with platina; if it be heated with contact of air, it is converted into a calx, at first whitish, which becomes more and more black, in proportion as the calcination proceeds. I have observed that the small globules of manganese, obtained by the process I have before spoken of, very soon change by the contact of air; they are tarnished, and become of a lilac and violet colour.

The action of manganese on earths, and the salino-terrestrial substances, has not yet been examined; the calx of this semi-metal gives a violet or brown colour to glass, susceptible of a great number of modifications, but easily destroyed by the action of combustible substances. Scheele has made a great number of ingenious experiments on this head.

The manner in which fixed alkalies act on manganese, is not known; but the calx of this semi-metal combines with the volatile alkali, and is revived. Bergman observes, that in this combination, a peculiar gas is disengaged, which he regards as one of the principles of the volatile alkali, but of which he does not speak fully. It appears to be the atmospheric mephitic, discovered to exist in volatile alkali, by Mr. Berthollet; and

and that the inflammable gas of this substance, acting on the oxygenous principle united to manganese, reduces it to a state less perfectly calciform, and of a white colour.

The vitriolic acid dissolves manganese and its calces; this last solution is coloured, but becomes clear by the addition of any combustible matter, such as sugar or honey. It affords a transparent vitriol in prismatic crystals with parallel sides. If it be distilled to dryness, sulphureous gas is obtained.

The nitrous acid likewise dissolves it, emitting at the same time red vapours. Its calx is not attacked by this acid, unless it be fuming, or some combustible body, such as honey or sugar be added. Alkalis precipitate from its solutions a white calx, soluble in acids, which, when heated, becomes black, and is calcined still more. Mr. Scheele thinks that this calx is charged with the phlogiston of the acid, and observes, that in fact, the black calx of manganese is very soluble in phlogisticated acids. Bergman thinks, that this semi-metal has a greater affinity with salts than most metallic substances; he places it in his table, near the top of that column, which contains the elective attractions of acids.

The muriatic acid likewise dissolves manganese, which gives it a deep brown colour; when this solution is heated, the colour disappears:

appears : water occasions a precipitate, and alkalis decompose it.

In the history of this acid we have seen, that when distilled from the calx of manganese, it becomes white, and approaches to the metallic state, by giving out a part of its oxygenous principle to the muriatic acid; or by taking away a portion of phlogiston, which Mr. Scheele admits to exist in this saline substance. The marine acid seems to have a stronger affinity with manganese, than the vitriolic; for the solution of this semi-metal by the latter, being poured into spirit of salt, forms a precipitate, which Bergman found to be muriate of magnesia, by the property it has of dissolving in spirits of wine; a property which the vitriol of the same metal does not possess.

The fluor acid dissolves the calx of manganese very sparingly, These two substances are more easily united, according to Scheele, by decomposing the vitriol, the nitre, or the muriate of manganese, by ammoniacal fluor.

The cretaceous acid dissolves a small quantity of manganese, by digestion in the cold. The vegetable alkali, or simple exposure to air, precipitate the metallic calx from this acid.

Scheele has examined the action of nitre, borax, and sal-ammoniac, on the calx of manganese. This calx disengages the acid
of

of nitre, by the assistance of heat; with vegetable alkali it forms a deep green mass, soluble in water, to which it communicates the same colour. The greenness arises from the iron contained in the manganese; and in proportion as this falls down, the solution becomes blue. Water and acids precipitate this alkaline solution.

Nitre heated in vessels made of glass, containing calx of manganese, communicates a violet colour to the glass, which is so much the deeper, as the calcination of this calx by the nitrous acid, is more complete.

Borax, melted with calx of manganese, assumes a brown, or violet colour.

Sal-ammoniac distilled from this metallic calx, affords volatile alkali, in part decomposed. Scheele, who made the same observation, informs us, that an elastic fluid, which he esteems to be one of the principles of volatile alkali, is at the same time disengaged. But he has not pointed out the nature of this fluid, which Mr. Berthollet has discovered in another way. This last chemist decomposes the volatile alkali, by means of metallic calces; in which process water is formed by the union of inflammable gas, one of the principles of this salt, with the oxygenous principle of the calces, while the atmospheric mephitic, or the other principle of the volatile alkali, is disengaged in the aeriform state.

The

The action of inflammable gas, of sulphur, or of plumbago, on manganese, or on its natural calx, is not known; arsenic, in the calciform state, appears capable of taking from this last a portion of its oxyginous principle, since it deprives glasses of colour, after they have become brown by means of manganese. Scheele believes that this phenomenon is a consequence of the manganese depriving the calx of arsenic, of the phlogiston it still retains, and to which the manganese has a strong affinity.

The action of manganese on neutral salts is not known: it gives a violet colour to borax and nitre, and causes the same colour to appear in glasses which contain this metallic calx.

To these properties Bergman adds, that manganese cannot be absolutely purified from the iron it already contains, and therefore, this semi-metal, like nickel, has not yet been obtained in a state of perfect purity. Scheele, in the accurate analysis which he has made of the natural calx of manganese, found it to contain iron, lime, ponderous earth, and a small proportion of quartz.

The black calx of manganese, called black magnesia, is used in glass-houses, to take away the yellow, green, or blue tinge from glass, intended to be of a clear white; a large proportion gives glass a violet colour. Scheele thinks that this mineral deprives glass of its colour,

colour, by combining with the phlogiston of such matters as alter it; but it is more probable that this phenomenon is a consequence of the action of the vital air separated from manganese by heat, on the colouring substances. Manganese is at present used in chemistry, to prepare the aerated or oxygenous marine acid.

C H A P. XII.

Of the Regulus of Antimony.

THE regulus of antimony, stibium, which ought to be called simply, antimony, is a heavy semi-metal, of a brilliant white, resembling that of tin, or silver; it is composed of plates applied upon each other, and presents on its surface a sort of crystallization, in the form of a star, or leaves of fern. It is likewise capable of crystallizing in trihedral pyramids. Immersed in water, it loses $\frac{1}{7}$ of its weight. It is easily reduced into powder, and has a very sensible taste, or action on the stomach, being powerfully emetic and purgative.

The regulus of antimony is seldom found native. It has been discovered by Mr. Anthony Schwab, at Salberg in Sweden. Mr. Schrieber, director of the mines at Almont, in Dauphiny, found it in those mines.

This

This native antimony is in large plates, and possesses all the properties of that procured by art, excepting that it contains one or two hundredth parts of arsenic.

Mr. Mongez, the younger, has discovered a native calx of antimony, in fine white needles, mixed with antimony, or grouped so as to resemble zeolite. He found this calx on native antimony from Chalanges in Dauphiny.

This semi-metal is most commonly combined with sulphur, and then forms what is improperly called antimony, and ought to be denominated ore of antimony. This mineral is of a blackish grey, in brittle plates or needles, of various magnitudes, joined together in different forms. It is sometimes mixed with other metals, particularly lead and iron; and is very common in Hungary, and in the provinces of Bourbon, Auvergne, and Poitou. Naturalists have multiplied the varieties of antimony, accordingly as the fibres of the mineral are parallel, divergent, irregular, chatoyant, &c. When antimony is mixed with a portion of arsenic, or when it is altered by alkaline and hepatic vapours, its needles are of a deep red, nearly resembling the fine flowers of cobalt, but rather more opake. The following are admitted as varieties of this ore.

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Variety

Variety

1. Antimony crystallized in separate hexahedral prisms, terminated by tetrahedral obtuse angled prisms.
2. Striated antimony, in the form of large irregularly formed needles, united in shapeless masses.
3. Antimony with divergent needles, issuing from one common center.
4. Lamellated antimony, the laminæ of various sizes, and resembling the lead ore called galena. This variety is sometimes brilliant, and is then called specular antimony.
5. Red antimony. It has the appearance of a granulated efflorescence, on the surface of the needles of antimony; it is sometimes crystallized in red needles, or prisms, of various degrees of brilliancy. Some naturalists call this native kermes, or golden sulphur of antimony.

The ores of antimony are not commonly treated with the intention of separating the semi-metal. In general, nothing more is done than the application of a sufficient heat to separate the sulphurated semi-metal from its gangue, and other metallic matters with which it may be mixed. For this purpose two earthen pots are taken, one of which is pierced at the bottom in many places; into this the ore is put; another pot

pot placed below the first, for the purpose of receiving the antimony in proportion as it melts, being sunk into the earth. A fire is then made about the superior pot, so as to produce a mild heat at the beginning, because the antimony is very fusible; but towards the end the heat is raised, that the whole of the antimony contained in the mineral may be melted out. At this period of the process a portion of other metals falls down, more especially iron, and forms a bed of scoriæ on the surface of the antimony. Though the antimony of Hungary is reckoned the purest, it is certain that all antimony which has been melted, if it be in the form of perfect needles, and without mixture of scoriæ, is equally proper for all the uses in which this mineral is employed. It must only be observed, that antimony often differs in the relative quantity of sulphur and regulus which it contains, and that it is of great consequence to make an assay of such specimens as are intended to be used in the preparation of such antimonial medicines, as are intended in all cases to have the same force or efficacy.

The process employed to separate antimony from its gangue, shews that it is very fusible. If the fire be raised when it is melted in open vessels, it parts with the sulphur, which is dissipated in yellow flowers. The metallic part is likewise very

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easily

easily calcined, and dissipated in white flowers. But if a mild heat, not sufficient to melt the antimony, be employed, the sulphur of the mineral is dissipated slowly, and by degrees; the metal uniting gradually to the base of vital air, and forming the grey calx of antimony. This operation cannot be well performed, unless the antimony be in a state of minute division, so as to present a large surface to the air. It is therefore reduced to powder, and exposed to a low heat in a shallow vessel of glazed earth. The process must likewise be conducted with caution at the beginning, because of the fusibility of the antimony; but in proportion as it goes on, and the sulphur is dissipated, the antimony becomes more refractory, and the fire may be raised to such a degree as to make the capsule, in which the mineral is contained, red hot. It is a proof that the operation is well conducted, when no other smell but that of sulphur is perceived during the roasting, and the matter does not gather into clots. But when, on the contrary, the antimony gathers together in lumps, and the sulphur is decomposed during its volatilization, which may be perceived by the suffocating smell of volatile sulphureous spirit, the heat is too great, and must be diminished.

Though sulphur seems to adhere very weakly to the regulus of antimony, in the
ore

ore we are treating of, it is not possible to drive it off intirely by roasting; and the grey calx of antimony always retains a considerable quantity, notwithstanding the calcination has been carried on to such a degree, as to deprive the metal of its reguline properties.

The grey calx of antimony urged by heat, without addition, melts into a glass of a red brown, or hyacinthine colour. This glass is variously fusible, and has different degrees of transparency, accordingly as the metal made use of was more completely calcined. If the calx contain a small proportion of sulphur, and a larger of the oxyginous principle, the glass it affords is transparent, and less fusible; and is glass of antimony properly so called. But if the calx contain much sulphur, and still nearly approaches the metallic state, it produces a more fusible and more opaque glass; this is called liver of antimony, because of its dull red colour, resembling the liver of animals. When the calx of antimony has been calcined so perfectly, as that it is difficult to bring it into fusion, a small piece of sulphur, or of crude antimony, may be thrown into the crucible, and the matter instantly melts.

The grey calx of antimony, the liver, or the glass, being heated in a crucible with their own weight of black flux, and a small quantity of black soap, or oil, are reduced,

and afford the pure regulus of antimony. The black flux in this operation, answers two intentions; the alkali which it contains unites to the sulphur, which has not been dissipated from the ore by the action of the fire, and the coaly matter favours the reduction of the metallic calx. This is the method of preparing the regulus of antimony in the large way for commercial purposes. The regulus is cast into flat globular pieces, which have a crystallization on their surface, in the form of the leaves of fern.

The regulus of antimony is scarcely altered by the contact of light. It does not melt till after ignition, and if it be strongly heated in closed vessels, it is intirely volatilized without decomposition. If it be suffered to cool slowly when melted, and the fluid portion be poured out after its surface is become congealed, the remaining part is found to be crystallized in pyramids, or quadrilateral pieces, as we have already observed.

The regulus of antimony melted in open vessels, is quickly calcined. White thick fumes arise, which fall again on the surface of the melted metal, or adhere to the cover of the crucible, in the form of small needles. This is a perfect metallic calx, to which the names of argentine, or silvery flowers of regulus of antimony, or snow of antimony, have

have been given. To prepare small quantities, a crucible is placed horizontally in a furnace, so that its rim applies to the opening of the furnace to which it is luted with clay. Regulus of antimony is put into the crucible, and the fire raised sufficiently to melt it, and cause it to emit fumes. The smoke being received in a second crucible applied to the first, becomes condensed in very slender white and brilliant needles, which appear to be quadrangular prisms. The snow and the flowers of antimony are not only susceptible of volatilization at the time of the deflagration, or burning of the semi-metal, but sublime alone if again urged by a strong heat. This calx may likewise be melted into an orange-coloured glass, paler and more transparent than is made with the grey calx of antimony. It is likewise much less fusible. The regulus of antimony is not altered by the action of combustible matters, but the snow of antimony is decomposed by substances of this nature, and resumes the reguline state. As this calx is highly calcined, and charged with a large proportion of the oxygenous principle, it very difficultly assumes the metallic state; and as it is likewise very volatile, it cannot be reduced but in close vessels. It even appears to be soluble in water, and to possess certain saline characters. Rouelle is the first who made this observation; and as

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several

several other metallic calces, and in particular that of arsenic, become saline and acid when they are saturated with the oxygenous principle, it may probably be hereafter discovered that the flowers of antimony possess the same property.

The regulus of antimony is scarcely at all changed by exposure to air, it being only observed that its surface becomes tarnished. It is not soluble in water, though several physicians have suspected that it communicates an evident emetic quality to that fluid. The snow and the flowers of antimony dissolved in water, communicate an emetic property; this action of the calx of antimony, together with its solubility in water, and its volatility, shews, as we have just observed, a sort of analogy between it and the calx of arsenic. Many mineralogists have hence supposed, that the ore of antimony is never free from arsenic; and it is certain, that this ore in powder, thrown on hot coals, as well as the regulus, emits an odour sensibly arsenical; and that when the operator has been exposed during a certain time to this vapour, he experiences its cathartic effects, and other symptoms of being slightly poisoned, as I have myself several times observed in my laboratory.

Earthy substances have no action on the regulus of antimony. Its calx enters without difficulty into the composition of glasses,
and

and gives them an orange colour, resembling that of the hyacinth.

The action of the salino-terrestrial substances, and alkalies, on the regulus of antimony, is not known; but the action of acids on this semi-metal has been more attended to.

When oil of vitriol is slowly boiled on the regulus, the former is decomposed and the latter partly calcined; a large portion of sulphureous gas is exhaled, and towards the end a small quantity of sulphur sublimes. The mass remaining after the decomposition of the acid, consists of much metallic calx, and a small proportion of semi-metal, combined with the acid in the state of vitriol of the regulus. The saline part may be separated by means of distilled water. This salt, when brought to a dry state by evaporation, is very deliquescent, and cannot be made to afford crystals. Fire easily decomposes it; pure water, the salino-terrestrial substances, and alkalies, likewise separate these principles. The calx formed by the solution, and precipitation from the vitriolic acid, is very difficult of reduction.

The nitrous acid briskly attacks the regulus of antimony, calcining a great part, and dissolving the rest, the acid being at the same time quickly decomposed. This solution may be well made in the cold. The salt which is produced, being separated from the

the calcined part by lixiviation, affords an antimonial nitre, which is very deliquescent, decomposable by fire, and by the same intermediaries as the vitriol of the regulus. The calx of antimony, formed by the nitrous acid, is very white, and is at the same time exceedingly refractory, and difficult of reduction.

The muriatic acid appears to act with more difficulty on the regulus of antimony, than the other acids; it however dissolves it by the help of a long digestion, and calcines it less than either the vitriolic, or nitrous acid. I have observed, that when this acid is left for a long time on the regulus in powder, it acts slowly, and dissolves a considerable quantity. The antimonial muriate, which is obtained in small needles, by a strong evaporation, is very deliquescent, melts in the fire, is volatilized, and is decomposed by distilled water, like the butter of antimony, from which it does not seem greatly to differ. Mr. Monnet, who has well described this combination, as effected by a considerable heat, observes, that the combination made with a calx of antimony, (as for example, the argentine flowers) differs greatly from that which is prepared with the regulus, in its fixity and manner of crystallizing in laminæ, like selenite and sedative salt. This salt is besides decomposable by water. We have had occasion to observe,
that

that in the solutions of the regulus by the muriatic acid, or by means of distillation, there is always a saline portion which does not rise by the action of fire, and resembles that which Mr. Monnet makes mention of. This depends on its having been strongly calcined by the acid. The same observation applies equally to almost all metallic solutions which exist in different states, accordingly as they contain metals more or less calcined. Mr. Monnet has established the fact, that twelve grains of calx of antimony are sufficient to saturate half an ounce of common muriatic acid, of which however he has not determined the strength. Bergman affirms, that the muriatic acid has a stronger affinity with antimony than the other acids have.

Aqua regia dissolves the regulus of antimony more readily than either of the acids which compose it; because the force of the nitrous acid is sufficiently moderated, to prevent the regulus from being intirely calcined; and, on the other hand, the activity of the muriatic acid is increased, on account of its union with the oxygenous principle, separated from the nitrous acid. The salt formed by the solution of the regulus in aqua regia, is very deliquescent, and may be decomposed like the other saline combinations of this semi-metal.

Antimony,

Antimony, or the natural combination of sulphur with the regulus, is in general more soluble, and is less calcined by acids than the semi-metal itself. It seems as if the sulphur partly defended the regulus from the action of these saline substances. Aqua regia has a moderate action on this mineral. It is a very good menstruum for separating the sulphur, which precipitates under the form of a white powder. Mr. Baumé directs that aqua regia, composed of four parts of nitrous, and one of marine acid, should be employed in this operation. When the action of the acid is over, the solution may be filtered, and the sulphur remains on the filtre. The weight of this shews the respective quantities of sulphur and regulus contained in the antimony. It must however be observed, that the sulphur, thus separated, is always mixed with a small quantity of the calx of antimony; so that this experiment cannot be esteemed as very exact, unless the portion of calx, mixed with the sulphur, be previously separated by means of acids.

The effect of other acids on the regulus of antimony, has not yet been examined.

This semi-metal decomposes many natural salts. Mr. Monnet, in his treatise on the solution of metals, has described an operation, by which he shews, that the regulus

lus decomposes vitriolated tartar. He melted in a crucible a mixture of one ounce of this salt, and half an ounce of the semi-metal. A yellow, vitriform, exceedingly caustic mass was produced, which was found to be an antimoniated liver of sulphur. This mass, being washed with hot water, afforded, by cooling, a reddish sulphur of antimony, or true kermes. He is of opinion, that the phlogiston of the regulus is united to the vitriolic acid with which it forms sulphur, and that the alkali of the vitriolated tartar, compounded with this sulphur, produces a liver of sulphur, which dissolves the calx of antimony. It will easily be understood, that according to the new doctrine, the semi-metal seizes the oxygenous principle of the acid, which last, by that means, is converted into sulphur. A series of experiments, which I have made on this subject, have convinced me, that many metallic substances are capable of decomposing vitriolic salts, in the same manner, as I shall shew in the following chapters.

Nitre is decomposed very readily by the regulus of antimony. When equal parts of this semi-metal and of nitre in powder are thrown by small portions at a time into a red hot crucible, a strong detonation takes place, and the regulus is burned by the assistance of the vital air afforded by the nitre. After this operation, the crucible
is

is found to contain the fixed alkali or base of the nitre, and the antimony in the state of a white calx. This calx is called diaphoretic antimony. The regulus of antimony is not usually employed in this operation, but the mineral or antimony itself: in which case, a larger quantity of nitre is required to be added; as for example, three parts to one of the mineral, in order that not only the regulus may be burned, but likewise all the sulphur to which it is united. The reason why the mineral is preferred in this process is, that the sulphur of the antimony renders the detonation of the nitre more rapid, and singularly facilitates the combustion of the regulus.

The matter that remains in the crucible after the detonation, is composed of the calx of antimony, united partly to the fixed alkali of the nitre, and partly to a portion of the nitre, which escaped the detonation. It likewise contains a small quantity of vitriolated tartar formed by the acid of the sulphur, and the fixed alkali of the nitre. This compound is called the solvent of Rottou, or unwashed diaphoretic antimony. The matter being thrown into hot water, the saline part is dissolved, and the metallic calx remains suspended. The water is poured off before subsidence, and the white and fixed calx is then suffered to fall down; this is called washed diaphoretic antimony.

It

It must be carefully dried, and then moulded into little square pieces. The water, which floats above, holds in solution the saline matters which were contained in the mixture, and also a portion of the metallic calx united to the alkali of nitre. If an acid be poured on this liquor, it seizes the alkali, and the antimonial calx is precipitated. This calx is called ceruse of antimony, or the materia perlata of Kerkringius. The liquor, which remains after the precipitation of the perlate matter, contains a small quantity of nitre, a small quantity of vitriolated tartar, and the new neutral salt, formed by the union of the acid to the alkali, which holds the metallic calx in solution. Though the last salt varies according to the acid made use of, it is very improperly called antimoniated nitre of Stahl. This salt in general is not nitre, because the vitriolic, or muriatic acids are usually applied to precipitate the calx of antimony; and when the precipitation is well made, no part of the calx remains in the salt.

The diaphoretic antimony and the ceruse may be melted into glass, as well as all the other calces of this semi-metal; but as they are in a very perfect state of calcination, they cannot be fused without considerable difficulty. For the same reason they are not easily reduced into the reguline form. They seem to be more difficult of reduction than

than even the snow of antimony, though they have stronger medical properties. They are likewise less soluble in water and in the acids.

The regulus of antimony appears capable of decomposing marine salt; for if a mixture of these two substances be heated in a retort, butter of antimony passes over into the receiver, according to the observation of Mr. Monnet. This chemist has not described the residue of the operation.

Regulus of antimony does not readily decompose sal-ammoniac, according to Bucquet, and butter of antimony is not obtained in this process, as Juncker affirms.

All combustible matters act more or less on this semi-metal. Inflammable gas alters its surface, and gives it a darker colour. It acts in a much more efficacious manner on its solutions. I have caused this gas, obtained from iron by spirit of vitriol, to pass through a solution of antimony in aqua regia. The latter immediately became turbid, and deposited a yellow orange coloured matter, similar to the golden sulphur, but never resembling kermes. The flowers of antimony, and diaphoretic antimony, whether dry, or moistened with water, being exposed in the same manner to the aqueous inflammable gas, did not appear to be at all changed.

Sulphur

Sulphur combines very readily with the regulus, and forms an artificial ore, perfectly similar to natural antimony. To obtain this combination, equal parts of sulphur and of the regulus are to be quickly melted in a crucible. A mineral in the form of needles of a deep grey is produced, which never contains so much as the half of its weight of sulphur, unless one part and a half of the latter substance be used with one part only of the semi-metal. I have likewise observed, that one ounce of the regulus melted in a retort, with one ounce of sulphur, produced ten drachms of antimony, which consequently did not contain more than two drachms of sulphur; and that the rest of this combustible matter, swelling up by the fusion, passed into the receiver. No more than one part of sulphur therefore is required to give the characters of antimony to four parts of the regulus; and hence we may observe, how necessary it is to make an assay of antimony before it is used for medical purposes, in order that the effect of different substances combined with this metal may be properly estimated.

Liver of sulphur completely dissolves regulus of antimony, and forms a yellowish mass, from which antimoniated sulphur may be precipitated by any acid. Hepatic gas acts on the solutions of this semi-metal, absolutely in the same manner as the inflam-

mable gas obtained by means of diluted vitriolic acid; which inflammable gas is produced by the decomposition of water, as we shall shew in our history of iron.

Regulus of antimony unites with arsenic and with bismuth, but these alloys have not yet been carefully examined.

Such are the principal properties of this semi-metal. It is likewise necessary to consider its ore, which is improperly called antimony. As this mineral is used in the preparation of a great number of important remedies, it follows of course, that its properties are much better known than those of the semi-metal it contains. The labours of the alchemists with this mineral have multiplied our knowledge concerning it, and no substance has afforded materials for a greater number of experiments. We have already seen, that by means of heat, a portion of the sulphur may be separated; that a grey calx results from this operation, which may be melted into glass, or liver of antimony, accordingly as its calcination has been more or less perfectly performed. That nitre, at the same time that it burns the sulphur, likewise calcines this metallic matter. But roasting, and combustion by the addition of nitre, are not the only means of separating the sulphur of antimony. This may be done by presenting to the mineral a body, which has a stronger affinity with
either

either of its component parts, than that part has to the other.

We have an instance of this kind of decomposition, in applying acids to crude antimony. These salts, and especially aqua regia, dissolve the semi-metal, and separate the sulphur which then floats above. The regulus appears to be more easily and completely dissolved when in antimony, than when it is pure, as has been before remarked. Iron, and other metallic substances, deprive the regulus of its sulphur.

Nitre is employed with success in the preparation of many valuable antimonial medicines. We have already seen, that when one part of antimony is detonated with three parts of nitre, the sulphur and the regulus are burned, and the residue is a white metallic calx mixed with alkali. If equal parts of nitre and antimony be detonated together, the detonation is of course weaker. For this reason it is necessary to throw the mixture by spoonful into a red hot crucible; whereas the other proportion used in the making of diaphoretic antimony, need only be once set on fire, when it continues to detonate, till it is intirely reduced to a white mass. When the detonation of the antimony and nitre, mixed in equal parts, is finished, the fire is increased, so

as to melt the whole; and instead of a diaphoretic antimony, a brown opake brilliant brittle mass is found in the crucible, which is a true liver of antimony covered with scoriæ. In this operation the nitre is not sufficient in quantity to burn all the sulphur; the remainder therefore holds the calx of antimony in solution. When the mixture is not heated sufficiently to melt it, nothing is obtained but a nitrous scoria, to which the name of false liver of antimony of Ruland is given. This matter reduced into powder, and washed with water, forms crocus metallorum; which is merely liver of antimony pulverized, and separated from the saline matters produced by the detonation of the nitre.

There are two other preparations analogous to the foregoing, which are true livers of antimony; the one is the ruby of antimony, or magnesia opalina, made by melting together equal parts of decrepitated marine salt, nitre, and antimony. This fusion, which takes place without detonation, affords a vitreous mass of a brown colour, very brilliant, and covered with white scoriæ. The other, improperly called the medicinal regulus, is prepared by fusing a mixture of fifteen ounces of antimony, twelve ounces of decrepitated marine salt, and three ounces of tartar. The result is a black shining very opake dense glass, not
at

at all metallic in its appearance. These two compounds, which differ from the true liver of antimony in certain extraneous properties, doubtless owe this difference to the marine salt which enters into their preparation, and whose effect on the mineral has not yet been ascertained.

When the regulus of antimony is required to be prepared in the small way in laboratories, no more nitre should be made use of than is necessary to burn the sulphur, and a substance capable of assisting in the reduction of the regulus must be added. With this intention, eight ounces of antimony in powder, six ounces of tartar, and three of nitre, are taken. These are mixed very accurately, and thrown by spoonful into a red hot crucible. The nitre detonates with the tartar and the antimony; black flux is formed, and the regulus of antimony melts and flows to the bottom. When the matter is well melted, it is to be poured into an iron cone, greased and made hot. The cone must be struck several times during the pouring of the mixture; after which, the whole being suffered to cool, the regulus of antimony is found at the bottom. The semi-metal is covered with black and reddish scoriæ, which rapidly attract the humidity of the air. When the regulus is pure, its upper surface is convex, and presents the regular

D 3

figure

figure of a star, which the exalted imagination of the alchemists led them to attribute to various causes. But it depends simply on the manner of the crystallization of the regulus during its cooling. The cooling begins at the sides, and the fluid matter being pressed out from the center towards the circumference, produces this appearance, which takes place only when the mass of regulus is small; for in the large masses of this semi-metal, the undulation of the fluid matter respects several centers, and instead of a star, it is found marked with impressions in the form of leaves of fern, which crystallizes under different angles. Reaumur has shewn, that a sudden cooling prevents this kind of crystallization in the form of a star; and that if one side of the cone be quickly cooled, no more than half a star will be seen*. The quantity of regulus obtained by this process, does not amount to the half of the antimony made use of, though this mineral often contains more regulus of antimony than sulphur. This is caused by a portion

* There is doubtless a relation between the manner in which metallic buttons crystallize at their surface, and the form which they affect, when by careful cooling, and a separation of the fluid portion, they are disposed in single crystals. The Abbé Mongèz is busied in inquiring into this relation in his researches on the crystallization of metals. F.

of the semi-metal combining with the saline matters which form the scorixæ.

The scorixæ, which flow above the regulus of antimony extracted by this process, are of a very compound nature. They contain the fixed alkali of the nitre, and of the tartar united to the sulphur of the antimony, and in the state of an hepar. This hepar holds a portion of the calx in solution, and is besides mixed with a small quantity of vitriolated tartar, formed by the vitriolic acid produced in the combustion of the sulphur, and united to a portion of the vegetable fixed alkali. Besides which, they contain a coaly matter afforded by the tartar. If these scorixæ be boiled in a large quantity of water, and the hot liquor be filtered, the coaly portion remains on the filtre, and the liquid, which is clear while it continues hot, becomes troubled by cooling, and deposits a reddish matter, which has been hitherto considered as an antimoniated liver of sulphur. The precipitate is called kermes mineral by the dry way. When the liquid affords no more, it may be evaporated, and a matter less coloured than the kermes is obtained, or true antimoniated liver of sulphur. It likewise affords vitriolated tartar. If instead of evaporating the liquid, any acid be poured in, a yellow orange precipitate, called the golden sulphur of antimony, is produced, which

does not appear to differ much from the kermes.

If antimony broken into small pieces be boiled, for a short time, in water charged with mild vegetable or mineral alkali, the alkali dissolves the sulphur of the antimony, and forms a hepar, which holds a part of the calx of antimony in solution. This boiling liquor being filtered, and suffered to cool, the kermes which it contains precipitates; and the cold liquor being filtered, the golden sulphur may be precipitated by means of acids. If an alkaline lixivium be boiled again on the residue of the antimony, more kermes may be obtained, but this kermes is paler than the foregoing; and the oftener the operation is repeated, the less kermes is afforded by the antimony. The alkali appears to dissolve more sulphur than regulus, and the mineral should not be boiled more than once or twice. This operation is called in general the preparation of kermes by the humid way.

The name of kermes was given to this preparation by a Chartreux friar named Simon, doubtless on account of its colour, which resembles that of the animal called kermes *, which is employed in dying. Kermes mineral has likewise been called

* The animal kermes, or scarlet grain used in dying, is the skin of a female insect, which fixes on the holm or ilex, and becomes extended by degrees in the manner of
a small

Poudre des Chartreux, because it was first prepared by persons of that religious order. The discovery of this medicine is due to Glauber, who prepared it with antimony, and a solution of nitre fixed by coal; but he has described his process in an unintelligible manner, and almost intirely under alchemical emblems. Lemery, who laboured much with antimony, and who has given us a preparation analogous to kermes, under another name, may be regarded as the true inventor. This remedy, however, was offered to the public as an intirely new invention many years after the publication of the works of that chemist, and in fact owes its celebrity to the singular cures effected by means of it in the hands of brother Simon. This friar had the composition from a surgeon named La Ligerie, who was not himself the inventor. This last affirmed that he received it from Mr. Chastenay, lieutenant in the army at Landau, to whom it had been communicated by an apothecary, who pretended to be a disciple of Glauber. Mr. Dodart, then first physician to the king,

a small cap or button; it has lost the form of rings, by which these animals are known: it is beneath this cap, that the eggs it contains are inclosed. The insects pierce the shell, and issue out, and the females, not having wings, fix and die on the leaves of the tree, after having been fecundated by the males, who have wings. Cochineal is another species of insect similar to this, as we shall shew in our account of the animal kingdom. Fourcroy.

applied

applied to La Ligerie to publish the receipt of kermes, which he accordingly did in the year 1720. Lemery the younger claimed the discovery in the name of his father in the Memoirs of the Academy, and with great justice, as most chemists still make use of the process invented by him for the preparation of this remedy.

The process described by La Ligerie consists in boiling for two hours a pint of rain water, with four ounces of the liquor of nitre fixed by charcoal, and a pound of antimony broken into small pieces. The boiling liquor is filtered, and the same antimony is again boiled with three ounces of fresh lixivium, diluted in a pint of rain water. Lastly, The second residue is boiled a third time with the preceding lixivium; two ounces of liquor of fixed nitre, and a pint of rain water being added. It is then filtered, and the kermes suffered to settle, which being washed till it is insipid, is then dried; and lastly, after spirit of wine has been burned upon it, it is reduced to powder. This process is very long, and affords but a small quantity of kermes; not more than two or three drachms from a pound of antimony. It is moreover very troublesome on account of the long ebullition, and the evaporation of the water. Lastly, It occasions a loss of more than three quarters of the antimony, on account of the small quantity

quantity of alkali employed in proportion to that of the mineral.

Mr. Baumé, who adopted the process of Lemery, gives two methods for the easy preparation of a large quantity of kermes in a short time; the one by the dry, and the other by the humid way. According to the first method, one pound of antimony is melted in a crucible, together with two pounds of very pure salt of tartar, and one ounce of sulphur; the whole being previously well pulverized. This melted mixture is poured out into an iron mortar, is pulverized grossly when cold, and is then boiled in a sufficient quantity of water. The liquor being filtered through paper, affords a kermes of a red brown in cooling; which, being first washed with cold, and afterwards with boiling water, till it is deprived of all saline matter, is dried, pulverized, and passed through a fine sieve.

To prepare the kermes by the humid way according to the same chemist, a lixivium of five or six pounds of caustic fixed alkali is boiled, with fifteen or twenty pounds of river water. Four or five ounces of antimony previously levigated, is thrown into this boiling liquor, and the mixture being well agitated, and suffered to boil for a very short time, is poured on the filtre. This liquor deposits much kermes during its cooling, which is to be washed in the same

same manner as the kermes produced by fusion. According to Baumé, this last process affords twelve or thirteen ounces from a pound of antimony, and he assures us that the two kermes are perfectly similar.

The theory of this operation, and the nature of kermes, are not yet perfectly known, notwithstanding the labours of many celebrated chemists. It is generally thought that the alkali dissolves the sulphur of the antimony, and that the hepar it forms dissolves the regulus. The semi-metal, however, is not totally dissolved, since in the process of Lemery by the humid way, a grey powder is precipitated during the ebullition, which may be melted without addition into a true regulus. The precipitation of the kermes by the cooling of the lixivium, which is at first reddish and transparent, but loses its colour in proportion as the kermes is deposited, is a phenomenon still more singular. This compound is by others thought to be a kind of antimony, with an over dose of sulphur, and soluble in the hot alkaline lixivium. In fact, if the alkaline lixivium be heated on a certain quantity of kermes ready prepared, a complete solution will take place. The lixivium, which has deposited kermes by cooling, still contains antimoniated liver of sulphur: by the addition of any acid, an orange coloured matter is thrown down, called golden sulphur

fulphur of antimony, which is much more emetic than the kermes, and is supposed to contain a less proportion of sulphur.

Geoffroy, who communicated in the years 1734 and 1735, several memoirs concerning the kermes mineral, made a great number of experiments with the intention of analyzing it. The action of acids is esteemed the most efficacious means that can be employed for that purpose. It is thought that these salts dissolve the semi-metal, and leave the sulphur disengaged, and that the respective quantities of these two substances can be thence estimated. One drachm of kermes, according to Geoffroy, contains sixteen or seventeen grains of the regulus, thirteen or fourteen grains of fixed alkali, and forty or forty-one grains of sulphur. Many chemists at present think, that the kermes does not contain an atom of alkali. Mr. Baumé affirms, that this salt is not one of its constituent principles, and that it may be entirely deprived of it by simple washing in a large quantity of boiling water. Mr. Deyeux, who has likewise made experiments on this substance, is of the same opinion. I have had occasion to make the same observation in a series of experiments made in conjunction with the Duke de la Rochefoucauld. But the most important circumstance relative to the kermes is, that it appears to be a very different substance, according

according to the several circumstances attending its preparation. It contains sulphur and regulus in various proportions; and there is reason to apprehend, that its effects must vary exceedingly, according as the proportion of these substances differ. In general, it seems that the state of the antimony; the variety of the proportions of its component parts; its greater or less division; the more or less caustic state of the alkali and its quantity; the quantity of the water; the time of ebullition; and many other analogous circumstances, occasion singular variations in the nature of kermes. In order that it may be the same in all cases, it ought to be prepared with substances always of the same quality, and in circumstances perfectly similar. Without entering into any very long details concerning the phenomena the kermes has presented, when treated by a great number of intermedia, I shall only add, First, that caustic alkalis greatly alter it, and dissolve it even in the cold. Secondly, That acids act with very different degrees of force on this substance, and that it is exceedingly difficult to determine with accuracy, by means of acids, the quantity, and the state of the semi-metal, or of the sulphur, which enter into its composition, because the sulphur, which is separated, always retains a certain quantity of the calx.

Caustic

Caustic alkalies act much more strongly on antimony than mild alkalies, and produce a much greater quantity of kermes of a deeper colour. Lime, or lime-water, digested on antimony in powder, affords, even without heat, in a certain number of days, a kind of kermes, or golden sulphur, of a beautiful red colour. Volatile alkali alters it in the same manner. When sal ammoniac is distilled from antimony, a pulverulent sublimate of a purple colour is obtained, which appears to be a kind of antimoniated liver of sulphur, with base of volatile alkali.

To conclude the history of the decomposition of antimony, we shall add, that many metallic substances have the property of depriving it of its sulphur, by their stronger affinity to that substance. Tin, iron, copper, and silver, produce these decompositions. Tin or silver, being melted together with antimony, unite with the sulphur, and leave the regulus. Iron and copper produce the same effect, provided they be first reduced to filings, or very small parts, and be previously made red hot before the antimony is added. The mineral accelerates the fusion of these metals, and the regulus is separated. The semi-metal obtained by these processes, is not pure, but retains a portion of the metallic substance made use of to separate the sulphur. Its colour

colour and appearance always indicate its impurity; it is distinguished under the names of jovial, cupreous, or martial regulus, according to the metals to which it is united.

The regulus of antimony is employed in many arts, and especially by the letter-founders. It was formerly used as a purge. Wine or water was poured into vessels made of this regulus, and suffered to stand for the space of a night; and the following day the liquor was drank: but as variations of the temperature of the place in which this operation was made, and of the acidity of the wine made use of, must have necessarily produced differences in the quantity of regulus taken up, it is with justice that this medicine was abandoned, as not being to be depended on. For similar reasons the perpetual pills, or small balls of this regulus, which were swallowed as purges, have been renounced. The state of the digestive juices, the nature of the mucus in the first passages, and the sensibility of different individuals, must have rendered their effects uncertain, and often dangerous.

Crude antimony, Rotrou's solvent, diaphoretic antimony, kermes mineral, and the golden sulphur, are the only antimonial medicines at present used.* Crude antimony is employed as a sudorific in cutaneous disorders. It is suspended in a linen bag in

* Many other antimonial preparations are in common use in Britain, for which see the Dispensatory. T.

the vessels in which the ptisans appropriated to these disorders are prepared; but many physicians deny it to have any virtue when administered in this manner. It is likewise taken in substance, being first finely levigated, and made up into pills for the same purpose.

The solvent of Routrou is greatly recommended in lymphatic disorders, produced the congelation of that liquid, as in scrophulous affections, and in general in all glandular tumours. Many physicians have no confidence in the effects of washed diaphoretic antimony. They consider this medicine as a pure calx of antimony, without any virtue whatsoever. We cannot, however, forbear observing, that this calx, in which Rouelle the younger has observed a remarkable degree of solubility, may produce singular effects in consequence of this property. It is likewise certain, that as the action of the gastric and intestinal juices on metallic calces are not known, it cannot therefore be determined whether a substance insoluble and insipid to all appearance has any virtue or no. Observation, however, teaches us, that this medicine produces but slight effects in eruptions, and in the most obstinate disorders of the skin, though employed for a long time. The unwashed diaphoretic antimony, or solvent of Routrou, which is much more active

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than the before-mentioned preparation, by reason of the alkali it contains, deserve to be preferred. In these affections a medicine, called Poudre de Chevallera, is used. It is diaphoretic antimony, calcined seven times successively during the space of two hours, with fresh nitre each time, and lixiviated after each operation. It does not sensibly differ from the washed diaphoretic antimony, because the semi-metal, once well calcined, as it is when detonated with three times its weight of nitre, cannot be further calcined, and for that reason in this preparation no succeeding detonation takes place. The present medicine is observed to be absolutely ineffectual when deprived of the alkali.

Kermes mineral is one of the most valuable antimonial remedies we are in possession of; it is attenuating, and is employed with the greatest success in pituitous affections of the stomach, the lungs, the intestines, and even the urinary passage. It is most commonly used in disorders of the breast, to assist expectoration. It ought not, however, to be administered, till after the inflammation is abated. It has likewise great success when given in repeated small doses in catarrhs of the breast, the humid asthma, maladies of the skin, glandular swellings, &c. It is administered in a dose from half a grain to two or three grains in proper liquids, or made up in pills. It
some-

sometimes causes vomiting, and very frequently acts as a sudorific or a diuretic.

The golden sulphur, on account of its being a violent emetic and cathartic, is not much used. It was formerly given in the same disorders as the kermes, but its effects are much more uncertain.

There are also many other preparations of antimony, which are used in medicine to great advantage; but as they are made up with vegetable matters, we shall speak of them in another part of this work. This metallic substance is one of the most important in the *Materia Medica*, and physicians cannot pay too great an attention to its properties. It is one of those upon which the alchemists, and even the chemists, have bestowed great labour, which has given rise to the numerous preparations above described.

C H A P. XIII.

Concerning Zink.

ZINK is a brilliant blueish white semi-metallic substance, crystallized in narrow plates. It has neither taste nor smell. It cannot be reduced into powder like the other semi-metals, but becomes flattened under the hammer, and may even be laminated,

nated, provided it has not previously been too much hammered. This experiment was made by Mr. Sage. When it is required to have zink in a state of extreme division, it must be granulated, that is to say, poured melted into cold water, or else reduced into filings. It has the inconvenience of choking up the files. Macquer affirms, that when heated nearly to melting, it becomes very brittle, and may then be pulverized. This property is very different from that of the metals, which become more ductile by the action of heat, and affords an advantageous process for obtaining this semi-metal in a state of extreme division. It may likewise be obtained in this state, by triturating it while melted, and keeping its particles asunder by continual motion, before they take the solid form by cooling. This operation must not be made in an iron mortar, because zink always dissolves a portion of this metal; a mortar and pestle of marble must be used.

Zink loses about one seventh of its weight by immersion in water. The particular facets which the pieces of zink met with in commerce present in their fracture, prove that this semi-metal has the property of crystallizing in a peculiar manner. Mr. Mongez has succeeded perfectly in his attempts to obtain this crystallization. It is composed of bundles of small quadrangular prisms,

prisms, disposed in all directions, and of a blue changeable colour, if exposed to air while the metal is still hot.

Mr. Sage considers zink as the most common of all the metals after iron. He affirms, that he found it in all the martial pyrites; and Mr. Grignon affirms, that the *cadmia fornacum*, obtained from the earthy ores of iron, contains much zink.

Native zink is very rare; most naturalists doubt whether it exists at all, yet Mr. Valmont de Bomare affirms, that he saw in the mines of *lapis calaminaris*, in the dutchy of Limbourg, and in the mines of Goslar, specimens of this in small flexible fibres of a greyish colour, and easily taking fire.

This semi-metal is most commonly found in the state of calx. It then constitutes *lapis calaminaris*, which has a great variety of forms. It is sometimes crystallized in cubes, in prisms, in leaves, or in plates; but most commonly it is in irregular masses. Its colour is likewise subject to variations. In some specimens it is white, in others grey and yellow, and in others reddish. Though very hard, it is never sufficiently so to give fire with the steel. It is found in quarries of considerable extent in the dutchy of Limbourg, the counties of Namur, and of Nottingham and Somerset in England. Marine substances, calcareous spar, &c. are often met with in calamines,

which proves that they have been formed by a subsidence from water. The lapis calaminaris is likewise called natural or fossil cadmia. Bergman, who has made a most extensive inquiry into the analysis of the ores of zink, found in almost all calamines, siliceous earth, clay, and iron, in different proportions; the calamines contain from four to thirty hundredth parts of metal.

Zink united to sulphur forms blende or false galena. This blende is ordinarily disposed in scales. Sometimes it appears crystallized in cubes more or less truncated. Its colours are various. In some specimens it resembles that of lead, but most commonly it is black or reddish. A yellow and transparent sort is found at Ronsberg in Norway, at Goslar, and Sainte-Mariæ. Some blendes are phosphoric when rubbed in the dark. There are some which have this property in so high a degree, that the stroke of a toothpick across their substance is sufficient to shew it. Blende has been called by the name of sterile nigrum, because when it has been melted to obtain the lead it appeared to hold, nothing was obtained; the zink having been driven off in consequence of its volatility. All blendes, when rubbed or dissolved in an acid, give out a very sensible smell of liver of sulphur. Cronstedt considers this ore as zink united to sulphur by the intermedium

termedium of iron. Mr. Sage thinks that it contains an earthy liver of sulphur.

Zink is likewise found in the saline state combined with the cretaceous and vitriolic acids. The first of these natural compounds is known by the name of vitreous ore of zink, or zink spar. This ore is white, grey, or blueish; gives fire with steel, is heavy, sometimes crystallized; also in stalactites or amorphous; it dissolves with effervescence in acids, and affords cretaceous acid. According to Bergman, one hundred grains contain sixty-five of calx of zink, twenty-eight of cretaceous acid, six of water, and one of iron.

Native vitriol of zink is found in rhomboidal crystals, and in white stalactites; it is often crystallized in fine needles, or silky fibres, resembling amianthus. In this state it is called plume-alum. It is found in Italy, and in the mines of Goslar, in the Hartz. The zink ores may be disposed in the following manner, according to the state in which the semi-metal exists,

S T A T E I.

Native Zink in flexible, greyish, and inflammable Fibres.

S T A T E II.

Calx of Zink; Calamine.

Varieties.

1. White calamine, in short tetrahedral prismatic crystals, grouped confusedly; it sometimes is greenish.

2. Calamine crystallized in pyramids similar to the dog's-tooth-spar, of a white grey, greenish, or reddish colour. Messrs. Sage, and Romé de Lisle think, that while this calamine is deposited, the calcareous spar is decomposed; it is often found, in fact, partly calcareous, and hollow in its internal parts.

3. Calamine solid, and, as if worm-eaten; it is furrowed, cellular, and crystallized, as it were, in dendrites.

4. Compact and solid calamine; lapis laminaris. That which is obtained from the county of Namur is always calcined; it is not allowed to be exported, without previously subjecting it to this operation.

5. Calamine in greenish or yellowish stalagmites.

6. Zeolitiform calamine, known by the name of zeolite of Friburg. Mr. Pelletier has discovered, that this pretended zeolite, of a pearl colour, contains in one hundred parts, from forty-eight to fifty-two, of quartz,

quartz, thirty-six of the calx of zink, and eight or twelve of water.

S T A T E III.

Zink mineralized by Sulphur ; Blende.

Varieties.

1. Grey blueish blende, with a metallic aspect, crystallized in cubes or rhombuses.

2. Black crystallized or irregularly formed blende.

3. Red or brown reddish blende.

4. Phosphoric blende, green, yellowish, or red.

5. Yellow greyish blende, mixed with galena and petroleum.

6. White blende.

7. Yellow blende of a wax colour.

8. Blende in a state of decomposition, whose laminæ are separated, and their brilliancy destroyed. It passes to the state of calamine.

S T A T E IV.

Saline Zink.

Varieties.

1. Spathose zink, or vitreous ore of zink.

2. Vitriol of zink in rhomboidal crystals, in stalactites, or in fibres of a silky appearance.

To

To make an assay of calamine, nothing more is necessary in general, than to pulverize and mix it with charcoal, and to heat it in a crucible covered with a plate of copper; the latter becomes yellow, and is converted into brass. Bergman has made a much more perfect analysis of calamines by the humid way. He applied the vitriolic acid to decompose pure calamines, and the zink spar. The solution contained vitriol of zink, and vitriol of iron. He decomposed the latter by a known weight of zink, and precipitated the decanted fluid by mild mineral alkali. He finds, by experiment, that one hundred and ninety-three grains of this precipitate contain one hundred grains of zink. From the weight of the precipitate he deducts the weight of the zink employed to precipitate the iron.

Most calamines being more compounded than those here mentioned, and containing quartz, clay, and chalk, combined with the calces of zink, iron, and even lead, Bergman first treats them three successive times with twice their weight of nitrous acid each time. By heating the mass to dryness, the acid calcines the iron, and renders it insoluble. He afterwards dissolves the soluble part in additional nitrous acid, the iron, the quartz, and the clay remaining behind. The acid takes up the calcareous earth, the calces of zink and of lead: marine acid is employed

employed to precipitate the latter; the vitriolic acid to separate the calx; and the zink is last of all precipitated by the Prussian alkali. The fifth part of the weight of this precipitate, he takes to express the zink contained in the calamine. He likewise employs a second method; vitriolic acid is distilled from calamine to dryness, the residue is afterwards lixiviated in warm water; from this lixivium he precipitates the iron and clay, by caustic volatile alkali; the zink remains suspended in the solution of vitriolic ammoniac.

The assay of blendes, after previous roasting, was formerly made in the same manner as calamines; Mr. Monnet is the first who affirmed that they might be conveniently assayed by solution in aqua fortis, which unites to the metallic substance, and separates the sulphur. The calx of zink is separated from the nitrous acid by distillation. Bergman has made the same accurate experiments on these ores as on the calamines, and has greatly improved on Monnet's method of the humid analysis. He first separates the water, the arsenic, and part of the sulphur they contain, by distillation; next he treats them with different acids, accordingly as these act more or less upon their contents, and precipitates the solutions by different re-agents. The ores of zink are not worked for the purpose of gaining the semi-metal. It is observed,

served, during the smelting of lead ores mixed with blende, that the zink is sublimed in the chimnies of the furnaces, in the form of calx, and produces greyish incrustations, named tuttia, or cadmia fornacum. Another portion is obtained in the metallic form, by cooling the anterior part of the furnace. The zink being driven up in the vapourous, form by the action of the fire, is condensed in this place, and falls in small grains into powder of charcoal, which covers a stone placed below. The semi-metal is preserved from calcination by the powder of charcoal, and is afterwards melted in a crucible, and run into moulds. Such is the process by which the greatest part of the zink found in commerce, is obtained at Rammelsburg, whether in the state of calx or metal. This zink is always united to a certain quantity of lead; it seems that the zink prepared in China, which comes to us under the name of tutenag, is much purer*, but the manner of preparing it is unknown. Mr. Sage assures us, that the English obtain zink in the large way, from lapis calaminaris, by distillation, but that their apparatus is kept a secret.

* Mr. Kirwan gives the name of tutenag to a variety of the brittle calamine of China, which was analysed by Mr. Engestrom, for which see the Memoirs of the Academy of Stockholm, for the year 1775. This ore is very rich, and contains from $\frac{60}{100}$ to $\frac{90}{100}$ zink.

Zink exposed to heat in close vessels, melts before ignition, and is volatilized without decomposition. If it be suffered to cool slowly in a vessel, by which the melted portion of the semi-metal can be suffered to run out, the remainder of the zink is found crystallized in needles, or slender prisms. Mr. Mongez, for this purpose, uses a vessel pierced at the bottom and at its sides, with a number of holes which he stops with earth of bones. When the zink cools at its surface, the holes are to be opened gradually, and the metal agitated by a red hot iron, introduced through one of these openings. This simple process occasions the melted portion of the zink to run out; the vessel is then to be shook, till no more melted metal runs out, and the cold portion crystallizes. If it be left in the vessel, it retains its metallic colour, but if it be exposed to air, it takes a tarnish of rainbow colours. When zink is melted with contact of air, it becomes covered with a grey pellicle, which is quickly converted into a yellowish earth or calx, and easily reducible. This calx weighs more than the zink made use of, but if the semi-metal be strongly heated, it burns with a white, or light greenish yellow flame, very brilliant, and similar to that of phosphorus. The current of this flame drives up the calx of zink, which is condensed in the air in the form of white, and
very

very light flocks, named flowers of zink, pompholix, nihil album, philosophical wool, or cotton. It is a perfect calx of zink, and weighs more than the semi-metal made use of to form it; Mr. Baumé having obtained from each pound of zink, sixteen ounces, six drachms, fifty four grains of flowers. It is not volatile, its sublimation being produced only by the rapidity with which the zink burns; it consequently remains very fixed when exposed to heat alone in a crucible. It preserves for a certain time a phosphoric light, sensible in the dark. It may be fused into glass, by a most violent heat; the glass of zink has a beautiful yellow colour.

The calx and the glass of zink, are nothing more than the semi-metal combined with the base of vital air. The glass does not appear to differ from the white calx, but by the more intimate union of the two principles. This compound is among the number of metallic calces which heat cannot destroy, and are not reducible without addition. Its decomposition cannot be effected, unless it be heated in contact with combustible bodies. A mixture of pompholix and charcoal being strongly heated, zink is obtained, and the charcoal is found to be partly burned, by virtue of the oxigenous principle it has taken from the metallic calx. Zink has therefore less affinity with
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the base of air than charcoal has, though it seems to be more combustible. This operation does not succeed well, but in close vessels, and for that reason the English are said to reduce lapis calaminaris by distillation.

Zink is scarcely alterable by the air. Its surface tarnishes a little, and appears to suffer a slight beginning of calcination.

Water has a strong action on zink; when this semi-metal begins to be red hot, it is then easily calcined, and a large quantity of inflammable gas is given out; a proof that the water is decomposed by the zink, which seizes its oxigenous principle. Messrs. Lavoisier and Meusnier have ascertained this fact in their experiments concerning the decomposition of water.

Zink has no action on the vitrifiable and argillaceous earths, but its calx enters into vitreous compounds, and colours them yellow.

Ponderous earth, magnesia, and lime, have no action on zink.

The caustic vegetable, and mineral alkalies, being boiled on this semi-metal, turn its surface black, and themselves acquire a dirty yellow colour, by holding in solution a certain quantity of zink. This may be separated by acids, as Mr. De Laffone has shewn. The volatile alkaline spirit acts less strongly on zink when heated, no doubt on account of

of its volatility; but by cold digestion it dissolves a small quantity. In these three solutions, a certain quantity of inflammable gas is disengaged, the production of which appears to be due to the water. So that it is this fluid which acts on the semi-metal, calcines it, and renders it partially soluble in alkalies.

The vitriolic acid diluted with water, dissolves zink in the cold. In proportion as the acid exerts its action, the semi-metal becomes of a blackish grey, much heat is produced, and a black powder is precipitated, which has not yet been well examined. A large quantity of inflammable gas is disengaged, which burns with a very bright flame, and detonates with pure air. This elastic fluid, whose smell is similar to that of the gas obtained during the solution of iron by the same acid, is certainly produced by the water; for oil of vitriol does not dissolve zink, without the assistance of heat, and then produces only sulphureous gas. The water therefore begins the calcination of the zink, and the acid afterwards dissolves the calx. When no more inflammable gas is disengaged, the effervescence ceases, the smell changes, and perfectly resembles grease beginning to be rancid. The liquor is whitish, and rather cloudy, but becomes transparent when diluted with water. It affords a white vitriol by evaporation,

ration, rather more soluble in hot than in cold water, and of which a portion crystallizes by cooling. Very regular crystals of vitriol of zink are easily obtained by exposing for some days to the air a solution of this salt made in boiling water, and a little evaporated: tetrahedral prisms are then formed, terminated by pyramids of four sides: the sides of these prisms are smooth. This form was pointed out by Messrs. Sage and Romé de Lisle, and I have myself remarked it. Mr. Bucquet has observed, that these prisms were rhomboidal. Mr. Monnet however affirms, that this salt crystallizes with great difficulty, and requires much evaporation, and sudden cooling, to afford regular crystals without consistence. The white calx, or flowers of zink, likewise dissolve in the vitriolic acid, and afford white vitriol.

This salt has a strong styptic taste. According to Hellot, it loses a part of its acid by the action of fire. This acid has the sulphureous characters, and becomes hot with oil of vitriol, according to the observations of Macquer. Vitriol of zink is not much changed by exposure to air, when it is very pure. It is decomposable by lime, and by the different alkalies. The calces of zink, precipitated by these substances, may be re-dissolved in acids, and even in alkalies. The volatile alkali becomes of a dirty brown
Vol. III. F colour,

colour, after dissolving it. The vitriol of zink decomposes nitre, and is itself decomposed. By distilling this mixture, two kinds of nitrous acid, which do not mix, are obtained, together with the glacial oil of vitriol; we shall speak more fully on this subject at the article of martial vitriol.

A vitriol of zink, prepared in the large way at Goslar, is met with in commerce under the name of white vitriol. It is made thus: blendes are roasted; a portion of the sulphur burns, and furnishes vitriolic acid, which dissolves the calx of zink. The roasted ore is then washed, and the lixivium being decanted, is exposed to evaporation, and affords crystals. The salt being melted by a gentle heat, so as to deprive it of its water of crystallization, and then suffered to cool, becomes condensed into white, opake, and granulated masses, resembling sugar. The vitriol of Goslar, when dissolved in boiling water, crystallizes by cooling. Its crystals are somewhat reddish, a circumstance to be attributed to the impurities of the salt, which is supposed to contain a small quantity of lead and iron. To purify it, zink may be thrown into its solution. The semi-metal precipitates the iron and the lead, because it has a stronger affinity with the vitriolic acid; and the liquor being filtrated, is consequently found to contain pure vitriol of zink. There is still greater reason to think, that the impurity of
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of the vitriol of Goslar consists in iron, from the circumstance of the zink met with in trade being magnetical, doubtless because it contains iron. Experiments concerning this semi-metal ought therefore not to be made, but with zink prepared by reducing the precipitate of white vitriol purified in the manner here shewn. We must however observe, that zink is very often magnetical only at that part of the piece which has been cut with scissars, or iron wedges.

The diluted nitrous acid combines very rapidly with zink, without the assistance of external heat. A considerable heat is produced in this solution, as well as in that wherein the vitriolic acid is used. The effervescence, which accompanies this combination, is occasioned by the disengagement of a large quantity of nitrous gas, which suddenly grows red by mixing with the air, when the operation has been performed in an open vessel, but which is colourless, and may be confined over water, by plunging the extremity of the vessel containing the mixture, underneath the orifice of a glass containing that fluid. This experiment shews, that zink decomposes the nitrous acid, and deprives it of a portion of its oxigynous principle. If the zink be mixed with a portion of iron, it is covered with a reddish ochreous powder, which is merely a portion of that metal calcined by the acid. If it be

pure, certain flocks of a blackish matter are precipitated, as is observed with the vitriolic acid. The nitrous acid holds a much larger quantity of zink in solution, than the vitriolic. Mr. Baumé affirms, that six ounces of this acid dissolved five drachms and a half of zink, in less than two hours. The nitrous solution of zink is of a greenish yellow, and not perfectly clear when newly made, but it loses this colour, and becomes transparent, after standing for some time. It is very caustic, and quickly corrodes the skin, though made with an acid diluted with water. I have obtained, by evaporation and cooling, crystals in tetrahedral striated flat prisms, terminated by pyramids of four sides likewise striated. The nitre of zink being put on hot coals, first melts and detonates as the portions become dry, and the detonation is attended with a small reddish flame. The same phenomenon does not appear, when the fusion is performed in a crucible. It cannot be dried, even by the mildest heat, without alteration; vapours of nitrous acid in this case escape, and it becomes of a brown red, and of the consistence of a jelly. If it be suffered to cool in this state, it preserves its softness for some time; but if it be kept heated for a sufficient time, it dries entirely, and leaves a yellowish calx. Hellot has obtained from the distillation of nitre of zink, a very fuming acid, and observed

served the red colour it assumes in melting. The nitre of zink quickly attracts humidity, and loses its regular form after some days exposure to the air, nothing remaining but striated and pointed prisms, whose figure can scarcely be determined. It is not known whether it is decomposable by other acids. Messrs. Pott and Monnet affirm, that zink has a strong affinity with all these salts, without having any preference for any one in particular. The flowers of zink form absolutely the same salt with the nitrous acid, according to Hellot.

The muriatic acid acts on zink as strongly as the nitrous. During the rapid effervescence which accompanies this combination, much inflammable gas is disengaged, which has the same properties as that afforded by the nitrous acid; and this last is known to consist of water decomposed by zink. Black flocks are gradually deposited, which some have considered as sulphur, others as iron, and Mr. Laffone thinks to be a calx of zink. This matter dissolves in acids; is not reducible to the metallic state, and becomes calcined on hot coals. Mr. Monnet thinks that it arises from certain foreign metallic substances, as for example, iron and copper, which are often found in zink. It certainly deserves to be more particularly examined. The solution of zink by the muriatic acid, is colourless, and does

not afford crystals by evaporation; when heated it becomes of a blackish brown, emits acrid and penetrating vapours of marine acid, and becomes thick. Exposed to the air for eight days in this state, it affords no crystals. By distillation it gives out a small quantity of very fuming acid, and a true butter of zink. Messrs. Hollet and Monnet have described this experiment very accurately; I have repeated it many times in my courses of lectures, and obtained a small quantity of yellowish acid, which was succeeded by a congealed matter in the neck of the retort. This butyraceous substance was of the finest milk-white colour, very solid, and formed of small radiated needles, in the manner of a stalactite. It is fusible by a gentle heat. I have preserved it for several years in well-closed vessels of glass. It has attracted very little moisture; the part which touches the glass is yellowish, and the bottom of the bottle presents rainbow colours. This alteration doubtless depends on the action of light. There remains in the retort, which is used for this distillation, a blackish vitriform and deliquescent matter. The butter of zink, which Hellot obtained, was blackish; he says, that the vitriolic acid disengages the muriatic. The calx of zink has the same habitude with this acid.

The cretaceous acid spirit in which zink or its calx are digested in the cold, dissolves, at the end of twenty-four hours, a considerable

able quantity, according to Bergman. This solution, when exposed to the air, becomes covered with a pellicle, which reflects various colours, and is merely a chalk of zink, called aerated zink by that celebrated chemist.

The action of the fluor and boracic acids on zink are not known.

All the solutions of zink in acids are precipitated by lime, magnesia, the fixed and volatile alkalies. The calx of this metal then appears in the form of white or yellowish flocks, according to the state of their solution, or the purity of the precipitant. This calx is reducible by the addition of combustible matters, is soluble in acids and in alkalies, either fixed or volatile. When more of the latter is added than is necessary to disengage the calx of zink, the precipitate disappears by degrees, and the liquor assumes a dirty yellow colour, which indicates the solution of the calx of zink in the alkali. When, instead of pure and caustic alkalies, the crystals of either the vegetable, mineral, or volatile alkali are used, the effervescence is very inconsiderable, the precipitate is white, and it is found, that the cretaceous acid unites with the calx, so that in these cases, two decompositions, and two new combinations are effected.

Zink has the property of decomposing several neutral salts. If it be treated in the dry way, with vitriolated tartar in a cruci-

ble, it decomposes the salt, and forms a liver of sulphur, in the same manner as regulus of antimony does. In this experiment the zink seizes the oxigynous principle of the vitriolic acid, and the acid passes into the state of sulphur, which the alkali dissolves. The hepar, formed by this combination, dissolves a portion of the calx of zink. All the vitriols are likewise decomposed by zink.

This metal, in filings, or in powder, causes nitre to detonate with singular rapidity. The mixture being very dry, and thrown by spoonfuls into a red-hot crucible, produces a white and red flame. The activity of the inflammation is such, that portions of burning matter are thrown to a distance out of the crucible, in such a manner as to require some precaution on the part of the operator. The zink burns by the assistance of the pure air afforded by the nitre, and is afterwards found in a calciform state, more or less perfect, according to the quantity of nitre used. One part of the residue is soluble in water. It consists of the alkali combined with a portion of the calx of zink, which may be precipitated from its solution by the addition of acids. Respour attributed to this solution the property of dissolving all the metals, if Hellot may be credited, who gives it as the alkahest of that alchemist.

Zink,

Zink, according to the experiments of Pott, appears capable of decomposing marine salt. It especially decomposes sal ammoniac with great facility. Mr. Monnet affirms, that this semi-metal triturated with sal-ammoniac, disengages the volatile alkali. Bucquet has observed, that when sal ammoniac and zink are distilled together, alkaline gas and inflammable gas are produced by the combination of the marine acid with the semi-metal: and he was sensible that the facility with which the zink disengages the volatile alkali, is a consequence of its strong action on the acid. The calx of zink likewise disengages it according to Hellot. The residue of this decomposition is muriate of zink, which may be sublimed into butter of zink.

When a solution of alum is boiled with filings of zink, a decomposition takes place, which affords white vitriol. The base of this salt therefore seems to have a weaker affinity than zink with the vitriolic acid. This fact was observed by Pott, and we shall have occasion to make the same remark with regard to many other metallic substances.

The effects of inflammable gas on zink have not yet been examined. I have only observed, that this semi-metal, plunged in inflammable gas, assumes, after a certain length of time, a beautiful blue and changeable colour; but I have not followed this alteration

alteration any further. It does not seem capable of reducing the calx of this semi-metal, which retains the oxigenous principle with great force.

Zink does not appear to combine with sulphur, but with the greatest difficulty. When these two substances are melted together, they remain distinct, without contracting any kind of union. Mr. Dehne, however, observed, that if they be kept for a certain time in fusion together, the zink is partly calcined, assuming at the same time a brown or greyish colour, and becoming much heavier. Mr. de Morveau discovered, since the time of the remark of Mr. Dehne, that the calx of zink unites easily with sulphur by fusion, and that a grey mineral is produced very similar to the blende of Huelgoet, from which yellow and prismatic needles are sometimes sublimed, and fix themselves to the cover of the crucible. Mr. de Morveau observes, that it is still more probable that blende is naturally formed by the combination of the calx of zink and sulphur, as native zink has never yet been found.

Mr. Malouin has not succeeded in his attempts to combine zink with the alkaline liver of sulphur, whether by the humid, or by the dry way, or by varying the proportions of these two substances to each other.

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The same chemist combined zink with regulus of arsenic. He observed, that this regulus does not unite so well with zink, as with the calx of arsenic; nevertheless, in an experiment, wherein he distilled a mixture of this calx with tallow and zink, he obtained a blackish mass resembling blende, but less consistent. It likewise appears that the zink seizes the vital air of the calx of the arsenic when they are distilled together, and that a portion of this semi-metal assumes the state of flowers, at the same time that a portion of the arsenic is revived. A series of experiments, made with a view to discover the reciprocal action of metallic calces and metals on each other, and to determine the elective attractions of the oxigenous principle with these substances, could not fail of proving highly instructive.

It is not known whether zink is capable of being alloyed with cobalt.

It does not combine with bismuth, and when these two semi-metals are fused together, the bismuth takes the lower place on account of its greater weight, and they may be separated by a stroke of the hammer.

Zink, fused with regulus of antimony, affords a hard and brittle alloy, which Malouin simply mentions, without pointing out any of its other properties.

Zink is of great use in the arts. It is employed

employed in many alloys, especially in tombac, prince's metal, and the various kinds of brass. Fine filings of zink are used to produce the white and brilliant stars in fire-works. Some persons have proposed to substitute this semi-metal instead of tin for lining copper vessels; the latter metal having been supposed to be insufficient to prevent the dangerous effects of that metal. Malouin, after having compared these metallic substances in Two Memoirs, printed among those of the Royal Academy of Sciences, for the years 1743 and 1744, gives an account of the experiments made by him respecting the lining of vessels with zink. From his researches it appears, that this lining spreads more evenly on the copper, is much harder, and less fusible than that of tin, and consequently more durable, and less subject to leave the copper uncovered. Macquer, who acknowledges these advantages, has however made several very important observations concerning the use of zink for culinary vessels, and thinks it dangerous, because it is soluble in vegetable acids, such as vinegar, verjuice, &c. and has a considerable emetic power. He proves this by the vitriol of zink, which was formerly employed as a vomit under the name of gilla vitrioli, and by the testimony of Gaubius, who mentions a celebrated remedy for convulsive disorders, named Luna fixata Ludemannii,

manni, which Macquer asserts to be the flowers of zink. This pretended luna fixata was strongly emetic in very small doses. But may it not be presumed that these objections, which are applicable only to the vitriol and the flowers of zink, cannot be applied to the semi-metal itself, nor even without further experiments to the salts formed by its combination with vegetable acids. Mr. de la Planche, doctor in medicine of the faculty of Paris, has changed this presumption into certainty, by experiments made with great care on himself. He took the salts of zink, formed by the vegetable acids, in a much stronger dose than the aliments prepared in copper tinned with zink can possibly contain them, and no dangerous effect followed the use of these compounds. However, since objects which relate to the health and the lives of mankind, cannot be treated with too much circumspection, it appears to me to be prudent and even necessary not to decide on this subject, till after a great number of experiments have been made concerning the nature of zink, and the black matter which separates during the solution of this semi-metal in acids, and which not being well known, may itself contain certain noxious substances; and especially till it has been well established by a great number of experiments, what the action of zink and its

its salts, formed with the vegetable acids employed in cookery, is upon the animal oeconomy.

The German physicians employ the flowers of zink with success as an antispasmodic in convulsions and epileptic fits. It is not much used in France, yet it appears that this remedy might be usefully administered in pills in the dose of half a grain each day. I have been assured, that a much more considerable dose has been taken at Edinburgh without any sensible effect. This fact is contrary to what Gaubius asserts concerning the emetic property of this calx of zink. Pompholix, tutty, &c. are used as excellent desiccative medicines, to be externally applied in disorders of the eyes.

C H A P. XIV. ♦

Concerning Mercury.

MERCURY or quicksilver has the opacity and brilliancy of metals, and next to gold and platina is the most ponderous substance we know : a cubic foot of pure mercury weighs 947 pounds ; it loses by immersion in water one thirteenth of its weight. As it is continually fluid, its tenacity and ductility are not well known, and it still remains a question among what species of
metallic

metallic bodies it ought to be placed. Like the semi-metals, it is volatile. It has a kind of ductility, resembling the metals; but its extreme weight, its habitual fluidity, its volatility, and the singular alterations it is capable of undergoing in many combinations, seem to justify the ranking it as a peculiar substance, which seems to belong to the metallic matters only by its brilliancy, weight, and combustibility: we shall therefore place its history between that of the semi-metals and the metals. It was long taken for granted, that mercury could not be deprived of its fluidity; but the academicians of Petersburg have proved the contrary. These learned men availed themselves of the excessive cold in the year 1759, to try many important experiments. They increased the natural cold by the assistance of a mixture of snow and fuming spirit of nitre, and by that means succeeded in causing a mercurial thermometer to fall to 213 degrees, according to the graduation of De Lisle; which answers to 46 degrees below freezing of the gradation of Reaumur. These philosophers, observing that at this degree the mercury descended no longer, broke the ball of glass, and found the metallic fluid frozen, in the form of a solid, which, on trial, proved capable of extension under the hammer. This experiment demonstrated that mercury, like all other metallic substances,

stances, is capable of assuming the solid form, and that it is then in a certain degree ductile. They could not determine the degree of ductility it is susceptible of, because every stroke of the hammer communicating heat to some part of the metal, melted it, and caused it to flow in that point.

Mr. Pallas, who succeeded in congealing mercury in the year 1772, at Krasnejark, by the natural cold of 55 degrees and an half, observed, that it then resembled soft tin, and was capable of being beat out into plates, that it broke easily, and that the pieces being brought together united again. In the year 1775 Mr. Hutchins observed the same phenomenon at Albany fort, and Mr. Bieker at Rotterdam in 1776, at the fifty-sixth degree below Zero. Lastly, this congelation was effected in the year 1783, in England, at a more moderate degree of cold; and it was determined that 32 degrees below Zero of the thermometer of Reaumur, is the term at which this congelation takes place. If therefore the mercury descended lower in the early experiments, the phenomenon must be attributed to the condensation of the solid metal. Hence we see, that this metal is the most fusible of any we know. The greatest cold known in the countries from whence it is obtained, cannot render it solid. It is probable, that
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if in the preceding experiments, the cold by which the mercury was frozen had been produced by insensible degrees, that metallic substance would have taken a regular crystallized form *.

The habitual fluidity of mercury has caused it to be esteemed a peculiar metallic matter, and it has been called *aqua non madefaciens manus*, water which does not wet the hands. It is true, that mercury does not wet the hands, nor most of the other bodies which may be wetted by water, oils, and other liquids; but this phenomenon depends only on the small degree of affinity which exists between that metallic fluid, and the bodies themselves; for when it is in contact with substances with which it can unite, as gold, silver, tin, &c. it becomes closely united to them, and wets them in such a manner, that they cannot be dried again, but by evaporating the mercury which adheres to them.

Mercury being a melted metal, always affects the form of globules when it is divided; and when it is confined in a bottle,

* The reader will find an history of the congelation of mercury, written by Dr. Blagden, in the *Philosophical Transactions* for 1783, Part 2. Hutchins's experiments made at Hudson's Bay, together with Mr. Cavendish's observations thereon, are likewise inserted in the same volume. T.

its surface appears convex. This effect depends both on the small degree of affinity which mercury has with glass, and the strong attraction that tends to bring the parts of this metal together; for if the fluid be placed in a metallic vessel with which it has an affinity, its surface then appears concave, like that of other fluids, because it combines with the sides of the vessels.

Mercury has no taste that the nerves of the tongue and palate can perceive; but it produces a very evident effect on the stomach and intestines, as well as on the surface of the skin. Insects and worms are infinitely more sensible of this taste than other animals, and for that reason it very soon kills them; and physicians administer it as an excellent vermifuge. It is by virtue of this property likewise that it cures the itch, and other cutaneous disorders, which many philosophers have thought to be produced by certain insects, which penetrate the texture of the skin. But this opinion has not been generally adopted, though several naturalists have described the animal, which causes the itch, &c.

Mercury rubbed for a short time between the fingers emits a slight peculiar smell. When it is very pure, and is agitated, it is
sometimes

sometimes observed, more especially in hot weather, to shine with a small phosphoric light clearly discernible. This phenomenon has been shewn with the mercury of the barometer by several natural philosophers *. If the hand be plunged in this metallic fluid, a sensation of cold is perceived, which seems to shew that its temperature is much beneath that of the atmospheric air; yet by plunging a thermometer in the same mercury, it is immediately seen that their temperatures do not differ. Does not this effect, which deceives us, and entirely depends on our sensations, arise from the great weight of this metallic substance? or is it produced by an increase of the evaporation of the fluid, which is continually emitted from the pores of the skin †?

* This phenomenon is produced by the efflux of the electric fluid into the vacuum over the mercury; that fluid being disengaged by the friction between the non-electric mercury, and the electric glass. T.

† The temperature of the animal being always higher than the common temperature of the atmosphere and of the mercury, the animal must of course be cooled by the mercury, at the same time that the mercury is rendered warmer. The large mass or density of the mercury, will cause the mean temperature to be nearer its original temperature, than a lighter fluid in the same case would have done; that is to say, the mercury will cool the animal more. It is besides an excellent conductor of heat. T.

Mercury when divided by continual agitation, such as that of the sails of a mill, changes by degrees into a very fine black powder, called Ethiop's per se, by reason of its colour. The mercury is not changed in this experiment, and by a slight heat, or by trituration in a warm mortar, it may be made to resume its usual fluidity and brilliancy.

Mercury is not found abundantly in nature. It is met with in the earth, either in the virgin state, possessing all its usual properties, or combined with acids, sulphur, or other metallic matters in the mineralized state.

Running mercury is found in globules, or larger masses, in friable earths and stones, and most commonly exists in the clefts or cavities of its ores. At Idria, in Spain, and in America, it is collected in the cavities and clefts of rocks. It is likewise found sometimes in clay at Almaden, and in beds of chalk in Sicily. Lastly, it is found in silver and lead ores, and mixed with white arsenic.

Mr. Sage mentions an ore of mercury, in the calciform state, at Idria, in Friuli; it is of a brown red, very soft, and granulated in its fracture; some globules of running mercury exist in it, and it is reducible by mere heat, without addition. Mr. Kirwan considers it as the combination of mercurial calx

calx and cretaceous acid; one hundred parts of the ore afford ninety-one parts of mercury.

In the year 1776, Mr. Woulfe found at Obermuschel, in the dutchy of Deuxponts, a crystallized, ponderous, spathose, white, yellow, or greenish ore of mercury, in which, by means of alkalies, he discovered the presence of the vitriolic and muriatic acids. It is a compound of vitriol of mercury, and corrosive sublimate. Mr. Sage affirms, that it contains eighty-six parts of mercury in the hundred. This chemist has described a corneous brown ore of mercury, from Carinthia. Mercury is most commonly found naturally combined with sulphur; it is then known by the name of cinnabar. This mineral substance is red, and has not a metallic appearance, though the quantity of sulphur is but small in comparison to the mercury; a proof that the combination of these two bodies is very intimate. Cinnabar is found in the dutchy of Deuxponts, in the Palatinate, in Hungary, in Friuli, and Almaden in Spain, and in South America, especially at Guamanga in Peru. It is sometimes compact, and its colour varies from a pale red, to a deep and blackish red. Sometimes it is found in transparent ruby-coloured crystals, and often in a kind of scales, or flattened laminæ. It is called native vermillion, and cinnabar in flowers, when

it is in the form of a very brilliant red powder. Lastly, It is found dispersed with different earths in selenite, mixed with iron, with pyrites, and with silver.

Mr. Cronstedt in his mineralogy, speaks of an ore of mercury, in which that substance is united to sulphur and copper; it is of a blackish grey, brittle and ponderous; its fracture is vitreous, and it decrepitates in the fire. It is found at Muschel Lansberg.

The same mineralogist affirms, that mercury amalgamated with virgin silver, has been found in the mine of Sahlberg in Sweden. Romé de Lisle has in his cabinet a piece which he thinks to be of this species.

Mr. Monnet, in his system of mineralogy, speaks of an ore brought from Dauphiny, by Mr. Montigny, in the year 1768, which contained mercury, sulphur, arsenic, cobalt, iron, and silver. It is grey, whitish, and friable. He found it to contain one pound of mercury, and three or four ounces of silver per quintal.

After this short account of the properties of the metal, the different states in which mercury is found in the earth, may be reduced to the following varieties.

STATE

S T A T E I.

Native Mercury.

Diffeminated in Earths and Stones, and most commonly in its own Ores.

S T A T E II.

Native Calx of Mercury.

S T A T E III.

Native Vitriol, and Muriate of Mercury.

S T A T E IV.

Mercury mineralized by Sulphur; Cinnabar.

Varieties.

1. Transparent cinnabar, red and crystallized in very short triangular prisms, terminated by triangular pyramids.

2. Transparent red cinnabar, in octahedral crystals, consisting of two triangular pyramids, united at their bases, and truncated.

G 4

3. Solid

3. Solid compact cinnabar, of a brown or bright red; it is sometimes foliated.

4. Red cinnabar distributed in striæ, on a stony matrix, or on solid cinnabar; it is sometimes composed of needles like cobalt.

5. Cinnabar in flowers; native vermilion. It is a cinnabar of a brilliant red, of a fatty appearance, which adheres to different matrices, under the form of a very fine powder; it is sometimes crystallized in very small needles, and then greatly resembles the foregoing variety.

S T A T E V.

Mercury combined with Sulphur and Copper; black and vitreous Ore of Mercury of Cronstedt.

S T A T E VI.

Mercury united to Sulphur, Arsenic, Cobalt, Iron and Silver.

S T A T E VII.

Mercury united to Silver, Native Amalgama of Silver.

An ore of mercury is known by pounding and mixing it with lime, or alkalies; this being thrown on a hot brick, and the whole

whole covered with a vessel in the form of a bell, the mercury is reduced into vapours, and condenses on the sides of the vessel. If the object be to discover the quantity of mercury it contains, the ore, after being pulverized and washed, must be distilled with such additional matters as are capable of seizing the sulphur, and disengaging the mercury. Water is placed in the receiver, for the purpose of condensing and collecting the mercury. If the ore be carefully weighed before the assay, and likewise the mercury obtained by distillation, the proportional quantity, which may be expected from any other mass of the ore, will be known.

Virgin mercury is easily separated, by pulverizing the stones in which it is mixed, and washing them in water. The metal precipitates, and the earth is carried off by the water. The ores of Idria, in Friuli, are treated in this manner.

Cinnabar is too volatile to admit of its sulphur being dissipated by roasting; but being almost always found mixed with a calcareous or martial substance, it may in general be decomposed by fire, without any other medium.

Mr. De Jussieu, in the Memoirs of the Royal Academy, for the year 1779, has described the process made use of at Almaden, in Spain, to obtain mercury from cinnabar.

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The ore containing iron, and a small quantity of calcareous stone, is put into furnaces, which are formed like reverberatory furnaces, and are heated by a fire made on a grate below. The furnace has no opening, except eight holes at its back part. At each of these a row of aludels is adapted, the last of which rests on a small structure, at a considerable distance from the furnace. Between the furnace and the structure at which the aludels terminate, is a small terrace or sloping bank, the higher part of which is even with the apertures of the furnace, and the lower with that of the support of the last aludel. It is consequently an inclined plane, and serves to support the intermediate vessels. If any mercury escapes for want of a proper closure, it is collected at the junction of the inclined planes of the terrace. When the fire is applied to the cinnabar, the iron and calcareous stone unite with the sulphur; and the mercury being reduced into vapours, passes into the aludels. After the distillation, all the aludels are carried into a square chamber, whose floor slopes towards a cavity in the middle, into which mercury is emptied.

Mr. De Jussieu observes, that the ores of cinnabar do not emit any exhalation noxious to vegetables, and that the environs of the mines of Almida, as well as the ground above them, are very fertile. He likewise remarked, that

that the working of this mine is not pernicious to the workmen, as has been supposed; and that those who work in the interior part of the mine, as felons, are the only persons who are subject to any danger; because the fires which they are obliged to make, volatilize a portion of the mercury, to the vapours of which they are continually exposed.

Mr. Sage, in the Memoirs of the Academy for the year 1776, has described the process employed to extract mercury from cinnabar, in the Palatinate. The furnace has a gallery charged with 48 retorts of cast iron, one inch thick, and three feet nine inches long, containing about sixty pounds of the matter to be distilled. These retorts are immoveably fixed in the furnace. A mixture of three parts of the ore well pounded, with one part of slaked lime, is introduced by iron ladles. The heat is produced by pit coal put in at the two extremities of the furnace, the sides being pierced in several places, to give sufficient air to maintain the combustion. The mercury rises by means of the re-action of the lime on the sulphur, and is collected in receivers of earth, adapted to the retorts and one third filled with water. This operation lasts ten or eleven hours.

Mercury obtained, or revived, from cinnabar, is very pure, and contains no foreign matter.

matter. The mercury met with in commerce, is seldom of this degree of purity, as it is almost always mixed with foreign metallic matters, whence it appears tarnished, and instead of dividing itself into neat globules, it flattens, and draws a tail.

Mercury does not appear to be altered by the action of light. It is very quickly, and regularly heated; that is to say, its dilatation is extremely regular, as Messrs. Bucquet and Lavoisier have shewn, by their experiments into the effects of heat on different fluids, read at the Academy of Sciences. This phenomenon proves, that mercury is the fittest fluid to ascertain exactly the degrees of heat, and forms the best thermometers.*

This metallic fluid, exposed to heat in closed vessels, boils in the same manner as liquids; a property not peculiar to mercury, but common to silver, gold, and most other metals. It is true, that as mercury is more fusible than any other metal, it boils sooner, and long before the red heat. Ebullition is nothing but the transition from the liquid to the vaporous state. The vapour of mercury, which is distinctly visible, in the form of a white fume, and, for the time, deprives the vessels in which it is received of their transparency, is con-

* De Luc ascertained this point in his *Recherches sur les Modifications de l'Atmosphere*. T.

densed

denfied by cold into drops of mercury, which are equal to the quantity put into the retort, and have fuffered no alteration, provided the mercury be extremely pure, and the diftillation carefully conducted. Mercury is therefore a very volatile fubftance, which may be diftilled like water, and in this property it approaches to the nature of femi-metals.

Boerhaave diftilled the fame quantity of mercury five hundred times fucceffively, and found it not in any refpect altered. It only appeared rather more brilliant, heavy, and fluid; doubtlefs becaufe the purification was very accurate. In this diftillation he obtained a fmall quantity of grey powder, which confifted of mercury in a ftate of extreme divifion, and became fluid and brilliant by fimple trituration in a mortar. It was an Ethiops per fe.

Diftillation is the beft method of purifying mercury, and of feparating the mixed metals, with which it is ufually vitiated in commerce. The foreign metal is found in the retort, in a brilliant cruft in fome parts, and blackifh in others. By weighing this refidue, the quantity of matter, with which the mercury was vitiated, is known.

The extreme weight of mercury caufed chemifts to imagine, that it contains the pure terreftrial principle, or vitrifiable earth, in great abundance; but this principle, when it abounds in bodies, gives them solidity;

lidity; and mercury is, on the contrary, very fusible; and again the earthly principle is fixed, and mercury is exceedingly volatile. These circumstances appearing contradictory, engaged Beccher to admit in this metallic fluid, a peculiar earth, which he denominated, as we have before observed, mercurial earth, and attributed to it excessive weight, together with volatility. Mercury was therefore, according to this chemist, a compound of three earths, viz. the vitrifiable, the inflammable, and the mercurial. The existence of the latter having never yet been proved, this opinion must therefore be considered as a mere unsupported assertion. Mercury appears like all metallic substances, to be a peculiar combustible body, whose first principles have not yet been separated. As to the vitrifiable earth, whose properties we have examined at the commencement of this work, we do not think that there is reason to admit it in mercury, more than in other metals, since no such principle has been extracted from it. The substance distinguished by that name by Beccher and Stahl, and supposed to exist in mercury, and in other metallic substances, is far from being a simple and earthy substance; as we have already observed in speaking of metallic calces in general.

Mercury, reduced into vapour, has a very considerable force of expansion, and is capable

pable of producing dangerous explosions, when confined. Hellot related to the Academy, that a certain person, being desirous of fixing mercury, had put a quantity into an iron ball, well foldered together. The ball being thrown into the middle of a heated furnace, had scarcely become red, when the mercury burst through its confinement with a considerable noise, and escaped. Mr. Baumé, in his experimental chemistry, relates a similar fact, of which Geoffroy, the apothecary, was witness.

Mercury when heated with access of air, changes at the end of some months into a brilliant red powder, of an earthy appearance, disposed in small scales. This powder, which no longer possesses the metallic aspect, is a true mercurial calx. The alchemists, who believed that the mercury was fixed in this experiment, called it, improperly, mercury precipitated by itself, or precipitate per se. As mercury, though very volatile, requires nevertheless the concurrence of air to calcine it; an instrument sufficiently commodious has been invented for this operation, usually called Boyle's hell. It is a large glass vessel, flat at the bottom, so that the mercury inclosed within it, forms a very thin stratum, and consequently presents a large surface. It is closed by a stopper, accurately fitted to its neck, and perforated by an exceedingly small hole. The vessel is placed
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on a sand bath, and the mercury heated till it boils. The opening in the stopper, on account of its minuteness, suffers the air to have access to the bottle, without suffering the mercury to escape. At the end of several months of digestion, a calx which is formed on the surface of the mercury may be separated. This is done by pouring the whole into a piece of close linen; the mercury passes through by pressure, and the red calx remains on the cloth. This process may be performed with equal success, with a flat bottomed matrafs, into which a sufficient quantity of mercury is poured, to form a thin stratum. The neck of the matrafs is afterwards drawn out into a capillary tube, and the point broken off. This method, contrived by Mr. Baumé, is better adapted to the calcination of mercury, because the vessel contains more air. It is likewise more easily heated, less expensive, and less subject to be broken, than Boyle's vessel. To succeed in this experiment, the mercury must be kept in a heat sufficient to make it boil gently night and day, for several months. By placing a number of such vessels on the same sand bath, a very large quantity of precipitate per se may be obtained, and a certain quantity may be had in fifteen or twenty days.

The precipitate per se is a true calx of mercury, or combination of that metallic substance,

substance, with the base of vital air, which it gradually seizes from the atmosphere. This is proved in a convincing manner, from the following circumstances: First, mercury can never be converted into precipitate per se, without contact of air. Secondly, this combination cannot be made, but with pure air, and does not take place in the different gases which are not pure air. Thirdly, the mercury in this experiment becomes heavier. Fourthly, when heated in closed vessels, it may be intirely reduced into running mercury, at the same time that a large quantity of elastic fluid is disengaged, in which combustible bodies burn four times more rapidly than in the air of the atmosphere. This is the same fluid that was first discovered by Dr. Priestley, and by him called dephlogisticated air. The mercury loses by reduction the weight it had acquired during calcination.

This last fact, together with the phenomenon of calcination, as far as relates to the necessity of the free admission of air, and its diminution in the operation, has induced Mr. Lavoisier to conclude, from analogy as well founded as any admitted in natural philosophy, that metallic calces are mere combinations of metals with the base of air. As the precipitate per se may be very well analysed by heat, and as it separates into two principles, pure or vital air, and run-

ning mercury, it is evident how strongly this valuable experiment tends to explain, and to prove the pneumatic theory. It is easily understood, that the base of vital air, or the oxigynous principle of Mr. Lavoisier, which was fixed in the mercury, becomes disengaged by recovering its elasticity with the assistance of heat. To reduce precipitate per se in this manner, it must be heated in vessels accurately closed. If the air has access to it, it remains in the state of calx, because it always finds in the atmosphere the body which alone has the property of calcining it. From this circumstance it was that Mr. Baumé insisted, that precipitate per se is not reducible, but on the contrary, sublimes in reddish crystals, of a ruby colour; while Mr. Cadet has maintained, that all precipitates per se are equally reducible into fluid mercury. Macquer has shewn, by an ingenious explanation, which perfectly agrees with the facts, that both these chemists were in the right; and that if the calx of mercury be heated with access of air, it sublimes totally, and may even be melted into a most beautiful red glass, as Mr. Keir, a learned Scotch chemist has asserted, in his translation of the Dictionary of Chemistry; but that the same calx, though capable of subliming with the contact of air, is reduced into a running mercury, and gives out vital air, when it is strongly heated in well-closed vessels.

Mercury

Mercury is not altered by exposure to air. It is only observed, that it becomes tarnished by the particles of dust, which the air deposits, and from that circumstance mercury has been called the loadstone of dust. All bodies, however, seem to have this property, though it is most sensible in this metal, on account of its brilliant surface. But it is not at all changed by this circumstance; nothing more being necessary to give it its original brilliancy, than filtration through a piece of shammy leather.

Mercury does not seem to dissolve in water. Physicians are, nevertheless, in the habit of causing a bag full of this metal to be suspended in vermifuge decoctions during their ebullition; and experience has shewn, that this practice is attended with good effects. Lemery affirms, that mercury loses part of its weight by this decoction. It is probable, that a principle, similar to that of smell, emanates from the mercury; a principle so fugitive and subtle, that its weight cannot be found. It is perhaps this principle that communicates the anthelmintic virtue to water.

Mercury does not unite to earths more than other metallic substances; its red calx or precipitate per se might perhaps fix in glasses, and colour them, as is observed to happen with the calx of arsenic.

The action of barytes, magnesia, lime, and alkalis on mercury, are not known.

The vitriolic acid does not act on this metallic substance, but when it is well concentrated. To make this solution, one part of mercury is poured into a glass retort, and one part and a half, or two parts of oil of vitriol are added; the mixture is heated, and a violent effervescence is soon after excited; the surface of the mercury becomes white, and a powder of the same colour is separated, which renders the acid opaque; and a large quantity of sulphureous gas is disengaged, which may be collected over mercury. This method, as we have seen in speaking of the vitriolic acid, is most commonly used to obtain that gas. A portion of water charged with sulphureous gas, and in the state of volatile sulphureous spirit, likewise passes over. When this distillation is urged, till the sulphureous acid no longer passes over, a white opaque very caustic mass is formed at the bottom of the retort, which weighs one third more than the mercury made use of, and strongly attracts the humidity of the air. The greatest part of this mass is a calx of mercury united to a small portion of the vitriolic acid. It is considerably fixed, according to the observations of Kunckel, Macquer, and Bucquet. In this operation the oil of vitriol is decomposed by a double elective attraction; the mercury.

cury, which is a combustible substance, unites to the oxigenous principle contained in the acid, while the heat disengages the sulphureous gas and the water. The metal must therefore be in the state of a calx, and must consequently have much more fixity than fluid mercury.

A portion of this vitriolic mercurial mass is soluble in water. When a large quantity of water is poured upon it, it mixes with the mass, and a white powder precipitates, if the water be cold; but if boiling water be used, the powder is of a beautiful brilliant yellow colour, which is so much the more lively, as the quantity of water and the heat are greater. This was anciently called turbith mineral, or yellow precipitate. The water which served to wash it is decanted, and a new quantity of boiling water is poured on the turbith, in consequence of which it becomes of a still more lively yellow. The washing is repeated a third time, to deprive it of all the vitriolic acid it contains. In this state it has no longer any taste, but is a mercurial calx, which when urged by fire in a retort, becomes first of a deeper colour, and is then reduced into running mercury, giving out a great quantity of vital air. Kunckel mentions this experiment, and it has been successfully repeated by Messrs. Monnet, Bucquet, and Lavoisier, who have made it in the most accurate manner.

manner. I have also repeated it many times with success. It proves, as we have observed, that the vitriolic acid is formed of sulphur, the oxigenous principle, and water; but a very violent fire is necessary to effect the reduction. It is perhaps for want of a sufficient heat, that Baumé did not obtain mercury; and that he affirms, that it cannot be reduced to its metallic form, but by the addition of a phlogistic or combustible matter. The vitriolic mercuriate being kept heated in the same retort in which it has been dissolved without unluting, or washing the mass to deprive it of the portion of acid, the decomposition nevertheless takes place, and it is reduced into running mercury, in proportion as the oxigenous principle, which it had taken from the vitriolic acid, becomes elastic, and consequently is converted into vital air by the combination of heat, according to the modern chemists.

The water which has been poured on the white vitriolic mercurial mass, is loaded with a portion of the acid which was not decomposed; but as calx of mercury is very soluble in that acid, a certain quantity is always taken up, so that the water holds in solution a true vitriol of mercury. By evaporating most of the water, this salt is deposited in small needles, the form of which has not been determined, because they are scarcely
consistent,

consistent, and quickly attract humidity. When boiling water is thrown on the crystals of the vitriol of mercury, they become yellow, and in the state of turbith mineral, because the water separates the acid, which adheres but weakly, and leaves the calx pure. The same event happens, when the water employed for the first washing of the mercurial mass is mostly evaporated, and the remainder afterwards diluted by the sudden addition of a large quantity of boiling water, instead of bringing it to crystals. If cold water be used, the precipitate is white; but it immediately assumes a yellow colour by the addition of boiling water. In this manner the solution of the calx of mercury may be rendered decomposable, or not, by water. For this purpose it is sufficient to evaporate it nearly to crystallization, or to charge the acid with all the calx it is capable of dissolving; for then the union of these two bodies is easily destroyed by water. If a small quantity of acid be added, water is no longer capable of causing a precipitation. I observed this in the most satisfactory manner, by dissolving well washed turbith mineral in weak spirit of vitriol; the solution is not saturated with mercury, and is at the same time not precipitable by water. But if the solution be charged with as much turbith mineral as it can dissolve by the assistance of heat, which may be done by

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adding that substance till it is no longer taken up; then the solution being poured into cold water, affords a white precipitate; or if into hot water, a yellow powder. In this state, if a small quantity of spirit of vitriol be added, it ceases to afford any precipitate. The white calx which the vitriol of mercury deposits, when cold water is poured on it, is very soluble, and may be made to disappear, by adding spirit of vitriol to the mixture.

Vitriol of mercury may be decomposed by magnesia and lime, a yellow precipitate being deposited; and fixed alkalies separate a calx of mercury nearly of the same colour. The caustic volatile alkali precipitates it, but very sparingly and slowly. It must be observed, that these precipitates of mercury are variously coloured, according to the state of the solution, and the nature of the precipitating substance, and their quantities likewise differ. They are very abundant when the solution is highly charged; and if, on the contrary, a solution which is not saturated with mercury, be decomposed, every portion of calx, which is separated by the first drops of the precipitate, is re-dissolved by the excess of acid. But when that excess is saturated, the precipitate becomes permanent. Hence it appears, that alkalies act on the acid combined with the mercury, more rapidly than on the acid

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at liberty. These different calces of mercury, precipitated by alkaline substances, are reducible in close vessels, without addition. To obtain them pure, it is necessary that they should be several times washed with distilled water.

The nitrous acid is decomposed by mercury with the greatest rapidity. The solution is effected without the application of external heat, and with various degrees of activity, according to the state of the acid. The common aqua fortis of the shops, acts on mercury without emitting any considerable quantity of red vapours. If a small quantity of fuming spirit of nitre be added, or if the mixture be heated, the combination proceeds much more rapidly, and a very large quantity of nitrous gas is disengaged. The mercury being reduced to a calx, remains dissolved. The solution is green, but it loses that colour at the end of a certain time. By this process, the acid takes up a quantity of mercury, equal to its own weight. Bergman has observed, in his dissertation on the analysis of waters, that nitrous mercurial solutions differ from each other according to the manner of their preparation; that which is made in the cold, and without the disengagement of red vapours, not being decomposable by the addition of distilled water; but if the solution be assisted by heat, and a large quantity of
nitrous

nitrous gas be produced, a precipitate will fall down on the addition of water. Such a solution cannot with certainty be made use of in the analysis of mineral waters, as we shall hereafter observe. This phenomenon is, I apprehend, owing to the same cause in the nitrous, as in the vitriolic, solution. Pure nitrous acid, assisted by heat, is capable of supersaturating itself with calx of mercury, and holding it suspended. This kind of solution with excess of mercury, will be precipitated by distilled water, which changes the density of the liquor, and diminishes its adhesion to the mercurial nitre; the precipitate therefore is a true turbith; which is very yellow, if warm water be poured on the supersaturated solution, but is merely white if cold water be used. The yellow colour may however be instantly communicated by washing in warm water. But, on the other hand, as the solution made in the cold, contains only mercurial nitre, without an excess of calx, distilled water occasions no precipitate. I think myself justified in accounting for the facts in this way, from a circumstance which I have observed a great number of times, viz. that the same mercurial nitrous solution may be rendered decomposable or not by water, accordingly as mercury or acid are added, and this may be repeated many times. For this purpose, mercury is to be dissolved
without

without heat in the nitrous acid, in as large a quantity as can be taken up; this solution is not decomposable by water, though nitrous gas has escaped: but if mercury be added to this by the assistance of heat, it becomes capable of affording a precipitate with water. By the same theory it is very evident, that a nitrous solution, which does not afford a precipitate by the addition of water, may acquire that property by simple heating. The heat, in fact, disengages nitrous gas, and this disengagement cannot be made without the destruction of a certain quantity of the acid. The proportion of mercurial calx to the remaining acid, becomes of course greater, and the excess is no longer combined, but adheres to the mercurial nitre, and is suspended in such a manner, that water can precipitate it easily. I have ascertained the fact, that mercurial solutions afforded only the excess of calx, by the addition of water, and do still retain a portion of true mercurial nitre, which may be decomposed by alkalies; in the same manner as happens with the mercurial vitriolic mass, washed for the preparation of turbith mineral. This portion of mercurial nitre may even be brought to crystallize.

The solution of mercury in the nitrous acid, is exceedingly caustic, and capable of corroding and destroying our organs. When it falls on the skin, it forms spots of so deep a purple,

a purple, that they appear black; these spots cannot be dissipated, but by the separation of the epidermis, which scales off. The solution is used as a powerful escharotic in surgery, by the name of mercurial water.

The solution of mercury in the nitrous acid, is capable of affording crystals, which differ from each other in their form, according to the state of the solution, and the circumstances accompanying the crystallization. These varieties being carefully observed, appear to consist of four distinct species, which I shall here describe,

1. A solution made in the cold, affords, by spontaneous evaporation, after several months, very regular crystals. Mr. Romé de Lisle has described them accurately. They are flat solids, of fourteen faces, formed by the union of two tetrahedral pyramids, truncated very near their base, and likewise at the four angles, which result from the junction of the pyramids.

2. If the same solution made in the cold be evaporated and left to cool, it deposits in the course of 24 hours, a kind of very acute prisms striated obliquely across their length, which are formed by the successive application of small laminæ, placed slopewise upon each other, like tiles, (botanists denote this by the term *imbricatum*). On a near examination of the elements of these prisms, I found that the laminæ which compose them
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are solids, with fourteen facets, similar to the crystals obtained by spontaneous evaporation, but smaller, and more irregular.

3. If a nitrous solution be made by a mild and regulated heat, it affords, by cooling, crystals, in flat, very long, and very acute needles, striated lengthwise; these are the most commonly obtained, and have been described by the greatest number of chemists, especially by Macquer, Rouelle, Baumé, &c.

4. Lastly, If this solution be more heated, so as to become decomposable by water, it usually takes the form of a white and irregularly formed mass, similar to the vitriolic combination. In this circumstance I have sometimes had a confused aggregate of small very long needles, of the appearance of tallow, and flexible, which followed the motion of the liquor. They were perfectly similar to the brilliant and silver coloured dendrites, which I have often observed on the sides of bottles, containing terra foliata tartari. It is proper to add, that this last solution, which affords only irregular and confused crystals, or shapeless masses, because it contains much superabundant calx of mercury, may be rendered capable of a more regular crystallization by the addition of acid.

These several mercurial nitres present nearly the same phenomena. They are very caustic,

caustic, and corrode the skin in the same manner as their solutions; they detonate on burning coals. It must be observed with regard to this property, that it is much more sensible in the very regular crystals of fourteen facets, than in those which have the form of small needles; and that it does not exist at all in the white mass precipitated from the strongly heated solution. The detonation of mercurial nitre is scarcely perceptible in crystals newly formed, but is rendered sufficiently sensible by suffering them to dry for some time on blotting paper. If they be then placed on an ignited coal, they melt, become black, and extinguish the place on which they are put; but their borders, which become dry, throw out small reddish sparks, with a noise similar to that of a slight decrepitation. When the very dry crystals are used, a stronger whitish flame escapes, which soon ceases.

Mercurial nitre melts when heated in a crucible, and emits very thick red vapours. In proportion as it loses its water and nitrous gas, it takes a deeper yellow colour, which is afterwards converted to an orange, and lastly to a brilliant red. In this state it is called red precipitate. If this preparation is intended to be employed in surgery as a caustic, it must be made in a matrafs by a mild heat, in order that it may retain a portion of the acid, to which it owes
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its corrosive power. Nothing remains after it has been strongly heated, but a calx of mercury, formed by the union of the metal to the oxigenous principle of the nitrous acid. Mercurial nitre distilled in a retort, affords a subacid phlegm, and nitrous acid at first, after which it becomes red precipitate; and a stronger heat being applied, occasions a large quantity of vital air, with a small portion of mephitic to be disengaged, the mercury being sublimed in the metallic form. It is from this experiment, made with the greatest accuracy, that Mr. Lavoisier has succeeded in proving the composition of the nitrous acid, as we have observed in the history of that saline substance.

Mercurial nitre becomes yellowish on exposure to air, and is very slowly decomposed. It is soluble in distilled water, in a larger quantity when boiling than in the cold, and consequently crystallizes by cooling. When this salt is dissolved in water, a portion remains, which is of a yellowish colour, and is not taken up. Mr. Monnet calls this matter nitrous turbith, and observes, that a large quantity may be obtained, by washing a nitrous mercurial mass, evaporated to dryness, such as is made for the preparation of red precipitate. If it be intended that the mercurial nitre shall be entirely dissolved, water must be employed, in which aqua fortis must be poured, until the precipitate disappears.

appears. I have observed, when boiling water is poured on the purest mercurial nitre, it immediately becomes yellow, and affords a nitrous turbith, of a deep colour, which when exposed to fire, becomes red more quickly than that which is made by the vitriolic acid. Nitrous turbith is in general more accurately calcined, than vitriolic turbith; which happens, as we have already observed respecting other combustible substances, from the nitrous acid suffering its oxigynous principle to be disengaged more easily; for which reason the nitrous acid is more decomposable than the vitriolic.

Ponderous earth, magnesia, lime, and alkalies, decompose mercurial nitre, and precipitate the metal in the state of calx. These precipitates are of different colours, weight, and quantity, according to the state of the solution. Caustic fixed alkalies afford a yellow precipitate, more or less brown, or of a brick colour, according as their causticity is more perfect. Volatile alkali precipitates the nitrous mercurial solution, of a grey slate colour, provided it be of that kind which water cannot decompose; but the same salt produces a white precipitate, in a saturated solution of mercury, such as water can precipitate. These differences have been accurately observed by Bergman. The precipitates are mere calces of mercury, more or less remote from the metallic state;

state; they are all reducible without addition, and by mere heat in closed vessels, and all afford pure air during their reduction. Those which have been precipitated by cretaceous alkalies, afford a certain quantity of cretaceous acid by the action of heat. The precipitates of mercury, formed by alkaline intermediums, have a property, discovered by Mr. Bayen, which must not be passed over in silence. They detonate like gunpowder, when exposed in an iron spoon to a gradual heat, after having been triturated in the quantity of half a drachm, with six grains of flowers of sulphur: after the detonation, a violet powder remains, which may be sublimed into cinnabar.

The vitriolic acid, and the salts into which it enters, likewise decompose mercurial nitre, on account of the stronger affinity of the vitriolic acid to mercury. If spirit of vitriol, or a solution of the vitriols of vegetable or mineral alkali, or of any other vitriolic salt, be poured into a solution of mercurial nitre, a whitish precipitate is formed, if the nitrous solution be not saturated; but it is yellower in proportion as the mercurial nitre contains less acid, and more metal. This precipitate is either vitriol of mercury, or vitriolic turbith. Mr. Bayen found that it always retains a portion of nitrous acid.

The muriatic acid has no sensible action on mercury, though it be one of those which

has the strongest affinity with that metal; but its action on mercurial calces, with which it forms a peculiar neutral salt, is very powerful. This combination takes place whenever the marine acid is brought into contact with the calx, in a state of extreme division. If a small quantity of muriatic acid be poured on a nitrous solution of mercury, this acid seizes the metal, and forms a salt which is precipitated in a kind of whitish coagulum, called white precipitate; the marine salts with base of alkali, or of any salino-terrestrial substance, abundantly produce the same effect, and form besides, earthy neutral salts, differing according to the nature of the base. But it must be observed, with respect to this precipitation, that it does not take place when the aerated, or dephlogisticated muriatic acid is used; because, though this acid takes the calx of mercury from the nitrous acid, the salt which it forms with that calx, is very soluble in water; whereas, the salt formed by the common muriatic acid, is not at all soluble.

This acid has a stronger affinity than the vitriolic acid with mercury, and occasions the same precipitate in the vitriolic solutions of that metal, as it does in the nitrous solutions. The compound of muriatic acid, and mercurial calx, may exist in two states, as we have before observed, according to the
simple

simple or aerated state of the acid; the latter constitutes corrosive sublimate, and the former, mercurius dulcis.

There are several processes for preparing corrosive sublimate, or corrosive mercurial muriate: in general, equal parts of dried mercurial nitre, decrepitated marine salt, and calcined or white martial vitriol, are mixed and put into a matrafs, two thirds of whose capacity are left empty. This vessel is plunged into a sand bath, and gradually heated till its bottom becomes of an obscure red; the vitriolic acid disengages that of the marine salt; the latter separates the mercury from the nitrous acid, which affords the oxygenous principle, so that it becomes dephlogisticated muriatic acid; it then combines with the mercurial calx, and forms corrosive mercurial muriate, which is sublimed in the form of flattened and pointed crystals to the upper part of the matrafs; the nitrous acid being dissipated in the form of nitrous gas. The residue is reddish or brown, and contains vitriol of soda, (formed by the union of the vitriolic acid with the base of the marine salt) and calx of iron. This salt is prepared in the large way in Holland, by triturating equal parts of mercury, marine salt, and vitriol together, and exposing the mass to a violent fire. In this operation the vitriolic acid, disengaged from the vitriol by heat,

appears to cause the muriatic acid to pass into the dephlogisticated state, since this last only is present in sufficient quantity perfectly to dissolve the mercury made use of. The corrosive mercurial muriate, may likewise be obtained by sublimation, from mixtures of martial vitriol, marine salt, and mercurial precipitates, by fixed alkalies, or turbith mineral.

Boulduc has given a very good process for preparing corrosive sublimate; but Spielman remarks, that it was before described by Kunckel, in his Chemical Laboratory. It consists in heating equal quantities of vitriol of mercury, and decrepitated marine salt in a matrafs; the sublimate is volatilized, and the residue consists of Glauber's salt. This method affords a very pure corrosive sublimate; whereas that used in commerce, and even that prepared in the small way, with martial vitriol, always contains a small quantity of iron. It is likewise more easy to execute, and more economical. We must here observe, that this operation proves that the vitriolic acid has the property of dephlogisticating the muriatic acid. Mr. Monnet affirms, that he has likewise obtained this salt, by treating, in a retort, very dry sea salt and mercury precipitated from its nitrous solution by fixed alkali. In all these preparations of corrosive sublimate, care must be taken not to break the sublimatory

matory vessel till it is entirely cool, in order to avoid the vapours of the sublimed salt. Lastly, there is another way of preparing the corrosive mercurial muriate more readily; it consists in pouring into a solution of mercurial nitre, a quantity of dephlogisticated muriatic acid, and evaporating the mixture. When the nitrous acid is evaporated, the liquor affords by cooling, crystals of corrosive mercurial muriate. There is reason to think, that when the dephlogisticated muriatic acid of Scheele shall be better known, the corrosive mercurial muriate of the shops will be prepared by this simple solution.*

Corrosive sublimate, or mercurial muriate, is a neutral saline substance, which deserves to be carefully attended to by chemists and physicians; it possesses a great number of properties which are highly necessary to be known, and of which we shall proceed to give a sketch. Its taste is exceedingly caustic; the smallest quantity being laid upon the tongue, leaves for a very long time an highly disagreeable styptic and metallic taste. This impression is carried even to the larynx, which it contracts spasmodically for a long time, especially in delicate persons. The action of this salt is still stronger on the tunics of the stomach, and the intestines. When it is applied to these

* See Scheele's Essays.

for any length of time, it corrodes them, and destroys their substance, for which reason it is one of the most violent poisons we know. The causticity of corrosive sublimate, appears to depend on the state of the mercury, as Macquer has very ingeniously observed. It cannot be attributed to the muriatic acid, as some authors have thought; for the mercury is more than treble the quantity of the acid. On this account, the salt renders syrup of violets green, rather than red, according to the observation of Rouelle. The taste of corrosive sublimate is besides excessively stronger than that of the muriatic acid. A dram of spirit of salt, diluted with water, may be taken with impunity; whereas a few grains of corrosive sublimate, dissolved in the same quantity of water, would poison without remedy. Bucquet thought that this extreme strength of taste depended on the combination of the two bodies, and from thence deduced one of his strongest proofs of the law of affinity, which establishes, that compounds have new properties, very different from those of either of their component parts.

Corrosive mercurial muriate is not sensibly altered by light; heat volatilizes, and semi-vitrifies it. If it be strongly heated with access of air, it is dissipated in the form of a white fume, whose effects on the animal œconomy are very active, and exceedingly

ly dangerous. When heated slowly, and by degrees, it sublimes in a crystalline and regular form, into prisms, so flattened, that it is impossible to determine the number of their faces. They terminate in very acute summits, and have been very properly compared to the blades of poignards thrown confusedly among each other. Fire alone is not capable of decomposing this salt, neither is it susceptible of alteration from the air. It is soluble in nineteen parts of water, and crystallizes by evaporation, in flattened prisms, very sharp, their extremity being similar to those obtained by sublimation. The spontaneous evaporation of this solution has several times afforded me oblique angled parallelopipeds, whose extremities were truncated slant-wise. Mr. Bucquet observed the same fact. Mr. Thouvenel has obtained crystals of this salt, in hexahedral prisms, a little flattened.

Ponderous earth, magnesia, and lime, decompose the corrosive mercurial muriate, and precipitate the mercurial calx. The phagedenic water made use of as a corrosive, by surgeons, is made by throwing half a dram of corrosive sublimate, in powder, into a pound of lime-water; a yellow precipitate is formed, which renders the fluid opake, and it is employed before this subsides. Fixed alkalies precipitate from corrosive sublimate, an orange coloured calx,

which becomes deeper coloured by keeping. The volatile alkali affords a white precipitate, which after a short time assumes a slate colour.

Acids and neutral alkaline salts, produce no change in the corrosive mercurial muriate, but it contracts an intimate union with sal-ammoniac, without decomposition. This very singular saline compound, which was highly esteemed by the alchymists, and called by them sal alembroth, salt of art, or of wisdom, &c. is formed either by sublimation or crystallization. The sal-ammoniac renders the mercurial muriate very soluble, since, according to Baumé, three ounces of water charged with nine drachms of sal-ammoniac, dissolves five ounces of sublimate. This solution is made with heat, and affords a solid mass in cooling. A preparation, called white mercurial precipitate, is made from this salt. A pound of corrosive mercurial muriate in powder, is thrown into a solution of the same quantity of sal-ammoniac; when the salt is perfectly dissolved, a solution of cretaceous vegetable alkali is added, which forms a white precipitate, which is washed and dried in the form of small lozenges. In this operation the fixed alkali disengages the volatile alkali of the sal-ammoniac, which precipitates the mercury in a white calx. Heat, and even light, give this precipitate a yellow colour.

Corrosive

Corrosive mercurial muriate is altered by inflammable gas. Sulphur does not change it, but liver of sulphur decomposes this, as well as all the other solutions of mercury; a black precipitate being produced, which arises from the combination of the sulphur with the mercury. Most of the semi-metals we have examined, are capable of decomposing this salt, and each decomposition exhibits peculiar phenomena, which well deserve to be examined.

If two parts of corrosive sublimate, with one of regulus of arsenic, be distilled by a mild heat, a transparent substance, of the consistence of oil, passes into the receiver, part of which soon condenses into a kind of white jelly, called corrosive oil, or butter of arsenic. If the heat be continued after the butter has passed over, running mercury is obtained: so that the process affords a method of determining accurately the principles of corrosive mercurial muriate. The butter of arsenic does not appear capable of crystallization, melts with gentle heat, and is so caustic, that it instantly destroys the organs of animals. It is soluble in water, which partly decomposes it; but its other properties are unknown. Calx of arsenic does not afford it.

The effects of cobalt, nickel, and manganese, on corrosive sublimate, have not been examined. Bismuth, regulus of antimony, and

and zink, decompose this last salt with great facility. When two parts of corrosive mercurial muriate, and one part of bismuth, are distilled together, a thick fluid substance is obtained, which congeals into a mass of a greasy appearance, fusible by heat, and precipitable by washing with much water; and in a word, a true butter of bismuth. Poli, who first described this experiment, in the History of the Royal Academy for the year 1713, affirms, that when this butter is sublimed several times, there remains in the vessel, a powder of the colour of oriental pearls, very soft to the touch, and as it were glutinous; he proposes this powder to be employed as a pigment.

If two pounds of regulus of antimony, and two pounds of corrosive mercurial muriate be accurately mixed together, heat is excited, which shews that there is a rapid action between them. If the mixture be distilled by a gentle heat, a thick liquor is obtained, which becomes fixed in the receiver, and often in the neck of the retort, in the form of a white mass, called butter of antimony. This butter usually weighs sixteen ounces and a few drachms. The residue is composed of mercury, and a grey powder of regulus of antimony, which floats on the metallic fluid. If the distillation be continued after the butter of antimony has passed over, a new receiver being adapted, running

running mercury is obtained, foiled by a small quantity of the butter of antimony, which it is impossible intirely to clear out of the neck of the retort. Mr. Baumé, who has accurately described this operation, affirms, that by this process, twenty two ounces of running mercury may be obtained, one ounce of regulus in powder, mixed with the mercury, and six drachms twenty-four grains of regulus melted in the retort. The latter is partly calcined into red and silver coloured flowers. In this experiment the regulus of antimony is calcined by the oxyginous principle, which is separated from the calx of mercury, and unites to the muriatic acid, with which it forms the butter of antimony. The same decomposition takes place equally well with crude antimony; one part of that mineral in powder being distilled with two parts of corrosive mercurial muriate, affording a butter of antimony. But the residue, instead of containing running mercury, exhibits a combination of sulphur with that semi-metal. This combination may be sublimed by a stronger fire, into red needles, improperly called cinnabar of antimony.

The butter of antimony may be prepared by several other methods. It is obtained in all cases, where the regulus in vapour meets the marine acid in the state of gas; but the decomposition of corrosive sublimate is the process

process which affords it with the greatest facility, and in the greatest plenty. This compound is in a solid form; it crystallizes in thick parallelopipeds; its causticity is sufficiently strong to destroy both animal and vegetable matters in a very short time. The action of light changes it: by a low heat it is melted, and becomes fixed by cooling. It is easily deprived of its white colour; and it may be rectified by distillation. When exposed to the air it attracts moisture, and is dissolved into a thick fluid, apparently oleaginous: it does not completely dissolve in water, the greater part being decomposed by that fluid. When butter of antimony is thrown into distilled water, a very abundant precipitate is immediately formed, which is known by the name of emetic powder, or powder of Algaroth, from the name of an Italian physician who first used it. It has been improperly called *mercurius vitæ*. This precipitate is a calx of antimony, which is violently purgative and emetic in a small dose, as for example, three or four grains. In order to obtain it very pure, it must be washed several successive times in distilled water. Its properties are different from the other calces of this semi-metal, which have not so strong an action on the animal œconomy. A portion of this calx remains dissolved in the water used in washing the butter of antimony, in which it

it is suspended by the acid taken up by that fluid. This fact may be ascertained by the addition of a small quantity of alkali, which occasions an abundant white precipitate. It is therefore the excess of calx with which butter of antimony is charged, that gives it the property of being decomposed by water, as well as that of taking the form of a solid mass. Butter of antimony dissolves with heat and effervescence in the nitrous acid; a large quantity of nitrous gas being at the same time disengaged with considerable agitation of the fluid. The butter of antimony disappears, and the liquid becomes of a yellow reddish colour. It is a solution of calx of antimony in aqua regia. The calx is soon deposited in the form of a powder, or white magma. If the solution of butter of antimony by the nitrous acid be evaporated to dryness immediately after it is made, a very white calx is obtained. This calx is diluted with its own weight of the same acid, which is likewise evaporated, and the same process is a third time repeated; after which the matter is calcined in a crucible kept red hot for about half an hour, and affords a calx, which when cold, is found to be white on the upper part, and of a rose colour below. These two portions mixed together, constitute the preparation called Bezoar mineral. Macquer considers it as a perfect calx of regulus of antimony, and thinks it absolutely

absolutely similar to diaphoretic antimony. But Lemery, who has carefully described this preparation, recommends, that it should be calcined till it has but a very slight degree of acidity; his intention therefore is, that it should retain a certain quantity of acid, which must necessarily make a difference between this precipitate and calx of antimony.

Corrosive mercurial muriate is decomposed by zink, as Pott informs us, and as I have myself many times experienced. If a mixture of two parts of this salt, with one part of zink in filings, or coarse powder, be distilled in a glass retort, a very white and solid butter rises, which crystallizes in small united needles, similar to the aggregates of which stalactites are composed. The mercury remains pure in the retort, and passes over after the butter of zink. This butter fumes slightly when taken out of the receiver, and melts with a mild heat, becomes coloured by inflammable vapours, and is partly decomposed by water, like butter of antimony.

The most singular property of corrosive mercurial muriate, relative to its alteration by metallic substances, and at the same time the most important of its properties, is its combination with running mercury. When saturated with this metallic fluid, it loses most of its properties, especially its taste

taste and solubility. To make this combination, corrosive sublimate was formerly triturated in a glass mortar with running mercury, added by a little at a time, till no more could be made to disappear. The quantity of metallic fluid, which the salt takes up by this process, amounts to three-fourths of its weight, as Lemery and Baumé have observed. The mixture was placed in small vessels, two thirds of which were left empty, and in this manner sublimed three times successively; care being taken each time to separate a white powder which is found beneath the sublimed matter, and is very corrosive. The product called sweet sublimate, *mercurius dulcis*, or *aquila alba*, or more properly mild mercurial muriate, differs from corrosive sublimate by its insolubility in water, by its insipidity, and by its crystalline form. The crystals obtained by slow sublimation, are tetrahedral prisms, terminated by four sided pyramids; two very long and tetrahedral pyramids are frequently united at their base, and form a very acute octahedron.

The process we have described for the preparation of *mercurius dulcis*, is inconvenient in many respects. The trituration of corrosive sublimate with running mercury, till the latter disappears, is very tedious and difficult, and at the same time a subtle powder rises of so pernicious a quality,

lity, that the operator is under the necessity of covering his mouth and nose with a cloth. The mercury is never absolutely made to disappear in the mortar, and the sublimations are very slow. Mr. Baumé advises a small quantity of water to be poured on the matters intended to be triturated; by this means the operation is rendered more easy, and the saline powder is prevented from rising. He likewise employs levigation, by which the extinction of mercury is greatly facilitated. Lastly, in order to be certain of obtaining mercurius dulcis, entirely free from sublimate, Zwelfer, Cartheuser, and Baumé, propose to pour on the mild mercurial sublimate, a quantity of warm water, in order to dissolve the corrosive sublimate, and afterwards to dry the portion of mercurius dulcis, which is then found to be very mild. Mr. Cornet, to avoid the noxious dust of the sublimate, when triturated with mercury, proposes to use the precipitate of mercurial nitre by the volatile alkali, which unites much better to corrosive sublimate than running mercury; but this precipitate not being as pure as crude mercury, the preparation into which it enters, cannot be so much depended on. Mr. Bailleau, apothecary at Paris, has communicated to the Royal Society of Medicine, a process for making mercurius dulcis, which is free from the imperfections and danger

danger of the common methods. It consists in forming a paste of corrosive sublimate and water, and triturating it with running mercury; the trituration in the course of half an hour, causes the mercury to disappear, because the water promotes its comminution, and the combination is completed by digesting the mixture on a sand bath with a mild heat. The matter, which at first is grey, becomes white, and forms a very mild mercurial muriate, which requires only one sublimation to render it perfectly pure.

Mr. Baumé has made many experiments on mercurius dulcis. He has proved that this compound cannot be charged with a larger quantity of mercury, and that it cannot exist in a middle state, between that of corrosive sublimate, and perfect mercurius dulcis: so that when a smaller quantity of mercury is mixed with corrosive sublimate than is necessary to cause it to pass to the state of mercurius dulcis, this last compound is formed in quantities proportioned to the dose of mercury added; and the rest of the sublimate is volatilized with all its properties, without being rendered at all milder. The two compounds may be separated by means of warm water.

The experiments of the same chemist likewise teach us, that it is possible to change mercurial dulcis into corrosive sublimate,

by subliming it with decrepitated marine salt and martial vitriol, calcined to whiteness. In this operation the marine acid, being disengaged and dephlogisticated by the oil of vitriol, seizes the calx of the mercurius dulcis, and converts it into corrosive sublimate. Mr. Baumé has ascertained another circumstance, which shews the great difference between mercurius dulcis and corrosive sublimate; namely, that it does not unite with sal-ammoniac, as sublimate does, in the preparation of sal-alembroth. He therefore advises the washing of mercurius dulcis with water charged with a small quantity of sal-ammoniac, in order that all the corrosive sublimate may be carried off. Lastly, he has discovered, that at each sublimation, the mercurius dulcis loses a portion of mercury, and consequently affords a small quantity of corrosive sublimate; so that by repeated sublimations, mercurius dulcis may be intirely changed into corrosive sublimate. From this last experiment it obviously follows, that the preparation known under the name of panacea mercurialis, which is made by subliming mercurius dulcis nine times, is so far from being rendered milder by these operations, as most chemists and physicians have supposed, that it does not at all differ from mercurius dulcis. This last assertion is established the more incontrovertibly, by the

the circumstance of its being necessary to separate a white powder which rises the first in each sublimation, and is in fact corrosive sublimate. It must be observed, that in the preparation of mercurius dulcis, a reddish powder remains in the bottles, which is a calx of iron, afforded by the martial vitriol used in the common method of making corrosive sublimate for sale. A portion of this calx rises with the salt in sublimation. Small pieces of glass are likewise not unfrequently found, which have been carried up by the vapours of the corrosive sublimate.

The modern experiments made on the dephlogisticated marine acid, tend greatly to explain the theory of the formation of mild mercurial muriate. It is now proved, that corrosive mercurial muriate is a compound of dephlogisticated or aerated muriatic acid, and the calx of mercury, and that mild mercurial muriate is formed by common muriatic acid, in combination with the same metallic calx. So that when running mercury is triturated with corrosive mercurial muriate, it seizes the excess of the oxygenous principle from the dephlogisticated muriatic acid, and by that means reduces it to the state of common muriatic acid; which dissolves a much larger quantity of calx of mercury, than the same acid surcharged with the oxygenous principle does.

The sedative acid does not immediately dissolve mercury; but it has a very evident action on that semi-metal, when in the californ state. These two substances may be combined by the way of double affinity. A solution of borax being poured into a nitrous solution of mercury, an abundant yellow precipitate is formed, as Mr. Monnet first observed. In this operation the soda of the borax unites with the nitrous acid, and forms cubic nitre, while the acid of the borax combines with the calx of mercury, in the form of a neutral salt, which being sparingly soluble, falls down. The filtrated liquor affords, by evaporation, fine and brilliant pellicles of mercurial sedative salt, which, by exposure to the air, become of a greenish hue. Sal-ammoniac renders this salt very soluble, and forms with it a compound, analogous to sal-alembroth; lime-water throws down a yellow precipitate, which changes to deep red; and vegetable alkali causes a white precipitate. According to the academicians of Dijon, the corrosive mercurial muriate is likewise decomposed by borax, which produces in its solution, a precipitate of a brick-dust colour. Water, boiled on this precipitate, becomes of a milky colour, by the addition of fixed alkali, which proves that it contains mercurial sedative salt.

The

The action of the sparry acid on mercury is not known, and that of the cretaceous acid is almost equally uncertain. It is only known, that the acid spirit of chalk does not attack this semi-metal; but the solutions of mercury decomposed by cretaceous lime and alkalies, afford precipitates very different from those produced by the same substances when pure and caustic.

Neutral salts have scarcely any action on mercury. Though this assertion is more especially applicable to the different vitriols, I have observed, nevertheless, that mercury becomes very quickly extinguished in vitriolated tartar.

Mercury does not appear capable of altering sal-ammoniac by distillation. Bouquet, who made this experiment, observed, that two parts of mercury are not well extinguished by one part of sal-ammoniac, and that the mixture does not afford volatile alkali by distillation. The Count de la Garaye, nevertheless, prepared with these two substances, a medicine, to which he gave the name of tincture of mercury. Macquer, who examined his process, found it to succeed perfectly well. It consisted in triturating one ounce of running mercury, with four ounces of sal-ammoniac, in a marble mortar, moistening the mixture with a small quantity of water, till the mercury entirely disappeared. This matter being

left exposed to the air five or six weeks, and from time to time agitated, is then to be triturated afresh, and afterwards exposed in a matraass on a sand bath, covering the powder to the depth of about two inches with good spirit of wine. The mixture being made to boil slowly, the spirit of wine assumes a yellow colour, and contains mercury, as appears from its whitening a slip of copper. From this experiment it appears, that the volatile alkali is gradually disengaged by the mercury; that sal-alembroth is formed, part of which is dissolved by the spirit of wine; and that the different quantity of the mercury, and the slow action produced during the maceration, are the causes of the difference between this experiment and that of Bucquet.

The action of inflammable gas on mercury is not known.

Mercury combines very readily with sulphur. When one part of this metallic fluid is triturated with three parts of flowers of sulphur, the mercury is gradually extinguished, and a black powder is produced, which is called *Æthiops mineral*, and whose colour becomes deeper some time after it is made. This combination is more quickly effected, by mixing mercury with melted sulphur. The mixture being stirred up immediately, becomes black, and very readily takes fire. When the *Æthiops* is perfectly made,

made, it must be taken from the fire, and the matter must be kept stirred till it becomes solid and in lumps. It must then be pulverized, and passed through a fine sieve. The *Æthiops* is not the most intimate combination which sulphur and mercury are capable of forming. When this compound is exposed to a considerable degree of heat, it takes fire, the greatest part of the sulphur burns, and after the combustion, a matter remains, which, when pulverized, is of a violet colour. To convert this powder into cinnabar, it is put into matrasses, which are heated till their bottoms become red, and kept in this state for several hours, till it appears that the matter is entirely sublimed. The artificial cinnabar is found sublimed to the upper part of the matrass, in crystalline needles, of a reddish brown. Cinnabar is of a lighter and more lively colour, when sublimed in retorts. The Dutch prepare in the large way, the cinnabar employed in the arts; the compound is not volatile, but requires a strong fire to sublime it. When much divided by levigation, it has a brilliant red colour, and is then called vermilion. If it be heated in open vessels, the sulphur, which is not equal to one fourth of its weight, burns gradually, and the mercury is volatilized. Many substances are capable of decomposing cinnabar, by virtue of their affinity to sulphur.

Lime and alkalies have this property ; when these are heated in a retort, with twice their weight of cinnabar, running mercury is obtained, and the residue is found to be liver of sulphur. Mr. Baumé has observed, that this decomposition takes place by the humid way, when pounded cinnabar is boiled with a solution of fixed alkali. It must be observed, that he employed the cretaceous alkali. Many semi-metals, such as cobalt, bismuth, and regulus of antimony, have likewise the property of depriving mercury of its sulphur. It will be hereafter seen, that almost all the metals, lead, tin, iron, copper, and silver, have likewise a stronger affinity with sulphur than mercury, and consequently decompose cinnabar. They may therefore be indifferently used, to separate the mercury from this compound. The metallic fluid obtained by these processes, is perfectly pure, and is distinguished by the name of mercury revived from cinnabar.

Mercury immediately decomposes liver of sulphur, but produces different phenomena, according to the nature of these compounds. It forms *Æthiops* with the fixed alkaline liver of sulphur ; and this *Æthiops*, in the course of several years, becomes red. With the fuming liquor of Boyle, it very quickly becomes converted into *Æthiops*, and in a few hours, or at most

most a few days, it assumes a brilliant red colour, and affords a very fine cinnabar. Turbith mineral, precipitate per se, red precipitate, and all the calces precipitated from solutions of mercury by the alkalies, exhibit the same phenomenon, more or less readily, with the fuming liquor of Boyle. It is likewise produced by pouring this liquor into solutions of mercury, and exposing the black precipitate, which results from these mixtures, to a new quantity of volatile liver of sulphur.

I have discovered, that running mercury, agitated in natural or artificial hepatised water, decomposes it very readily, and is changed into Æthiops.

The action of mercury on regulus of arsenic is not known. Cobalt does not unite with it. Mercury dissolves bismuth very readily, with which it combines in all proportions: from this combination a brilliant friable matter is produced, which is more or less solid, according to the quantity of bismuth it contains. This amalgam is capable of crystallizing in four sided pyramids, which sometimes unite together in octahedrons. But it most commonly crystallizes in thin laminae, which have no regular form. This crystallization is obtained by melting the combination, and suffering it to cool slowly. When it is heated in a retort, it does

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does not part with its mercury, but with great difficulty.

Mercury does not unite either to nickel, or to regulus of antimony. It combines with zink by fusion. The amalgam formed with this last metal, is solid, but becomes fluid by trituration. When melted, and suffered to cool slowly, it crystallizes in laminæ, which appear square with rounded edges.

Mercury is of the most extensive use in the arts, such as gilding, silvering of glasses, constructing of meteorological instruments, metallurgy, &c. it is used in medicine in a great variety of forms.

1. Crude mercury was formerly employed in the iliac passion. It is still boiled in water, to which it communicates a vermifuge property. Mixed with fat substances, it forms an ointment, used in venereal disorders.

2. Turbith mineral has likewise been recommended in the same disorders, in the dose of a few grains. This medicine is emetic and purgative.

3. Mercurial water is used by surgeons, as a powerful escharotic. Red precipitate answers the same purpose. A citron coloured ointment is prepared with hog's lard and the nitrous solution of mercury, which is a certain cure for the itch.

4. Corrosive sublimate has been recommended by Sanchès, and Van Swieten, in
venereal

venereal disorders. A few grains are dissolved in brandy, and a spoonful of this solution is taken at a time, in a large quantity of mild liquid. The exhibition of this remedy requires great care, more especially with regard to the state of the stomach and lungs. Mercurius dulcis, given in the dose of twelve or fifteen grains, is a purgative, and in the dose of three or four grains, is an alterative. The phagedenic water is used in surgery, to corrode and destroy fungus, or proud flesh, &c.

5. Mercurial sedative salts have been used with success in venereal disorders, by Mr. Chauffier the younger, of the academy of Dijon.

6. Cinnabar is considered as an anti-spasmodic and sedative medicine. It enters into the composition of the pulvis temperans of Stahl, which is prepared according to the Pharmacopeia of Paris, by accurately mixing three grains of vitriolated tartar and nitre, with two scruples of artificial cinnabar. This compound is still used, by exposing the patients to its vapour. It then constitutes one of the methods of treatment of venereal disorders, by fumigation.

All the preparations of mercury, which are internally given, produce very beneficial effects in other disorders, as well as those of the venereal kind; such as most disorders of the skin, scrophulous disorders, lymphatic

phatic swellings, &c. We cannot however forbear observing, that these medicines, more especially the saline mercurial preparations, ought not to be applied but by experienced and cautious physicians; and that it is dangerous to the health, and even to the life of men, that mercurial remedies should be in the hands of a great number of persons, who, generally speaking, are deficient, not only in the knowledge which is necessary to administer them with success, but even in that knowledge which might enable them to avoid danger. I have myself been more than once witness to the unhappy effects of these preparations, caused by the unskilfulness of those who have employed them with that rashness which commonly accompanies ignorance. This subject appears to be of sufficient importance, to deserve the attention of the legislature.

C H A P. XV.

Concerning Tin.

TIN, or Jupiter of the alchymists, is an imperfect metal, of a whiter colour than lead, but not quite so white as silver. It is easily bent, and produces a crackling noise when bent; a phenomenon which we have already observed, though less evidently,

ly, in zink, and which has been urged by Malouin, as an instance of similarity between that semi-metal and tin.

This noise appears to depend on the sudden separation of the parts of the metal, and seems to shew, that a fracture takes place, though tin resists very little the effort which is made to bend it.

Tin is the lightest of all metals; it is sufficiently soft to be scratched with the nail. In water it loses about one seventh of its weight. It has evidently a smell, which becomes much stronger by heating or rubbing. It has likewise a peculiarly disagreeable taste, so strong, that some physicians have supposed it to have a sensible action on the animal œconomy, and consequently have recommended it in several disorders. Its extreme softness renders it scarcely at all sonorous. Tin is the second among metals, in the order of ductility; it is reducible beneath the hammer into laminæ, thinner than leaves of paper, which are of great use in many arts. Its toughness is such, that a wire of tin, of the tenth of an inch in diameter, supports a weight of forty-nine pounds and a half without breaking. The Abbé Mongez did not succeed in his attempts to crystallize tin; but Mr. De la Chenoye, one of my pupils, has succeeded, by fusing the tin for a number of successive times, by which means he obtained a rhom-

a rhomboidal assemblage of prisms or needles, united longitudinally to each other.

Most mineralogists still doubt the existence of native tin; some authors however affirm, that it has been found in Saxony, in Bohemia, and in the peninsula of Malacca. It is strongly affirmed, that it exists in the mines of Cornwall; and Mr. Sage has described a specimen of this tin given him, by Mr. Woulfe, a chemist of London. This piece is grey and brilliant in its fracture; when beaten on the anvil, it forms brilliant and flexible laminæ. Tin is more commonly met with in a white ponderous opaque calx, crystallized in octahedrons, or four sided pyramids; its texture is lamellated and sparry. Bucquet considers it as a true spar of tin. Sage thinks that these crystals are mineralized by the muriatic acid; perhaps, like the spathose ore of iron, they may be a combination of the calx of tin, and the cretaceous acid. This white ore of tin was classed among the ores of iron by Cronstedt.

The appellation of tin ore is given more especially to bodies of a very deep red, violet, or black colour, and of more considerable weight than any other mineral substance. These ores are sometimes crystallized in regular cubes, and exhibit groups, dispersed on a bed of quartz, or fusible spar; they very frequently form masses, without

without any other crystallization. Most naturalists agree in supposing the coloured ores of tin to be combinations of this metal with arsenic, and they attribute their excessive weight to the absence of sulphur. Messrs. Sage and Kirwan think however, that they do not contain any arsenic; and the former affirms, that it is not necessary to roast them, unless they be mixed with arsenical pyrites, which is a very common circumstance. Bergman admits the existence of sulphurated tin in nature among the minerals of Siberia. This sulphureous ore was externally of a golden colour, like aurum musivum, and its internal part presented a mass of radiated crystals, white, brilliant, and brittle, and assuming changeable colours on exposure to air. It contained a small portion of copper.

There have been no mines of tin found in France. Mr. Baumé however suspects, that it might be found in the neighbourhood of Alençon, and in some cantons of Britany, because rock crystals are found, which appear to be coloured by that metal. The countries where they are the most abundant, and are worked, are the counties of Cornwall and Devonshire, in England; Germany, Bohemia, Saxony, the Island of Banca, and the Peninsula of Malacca, in the East-Indies. Many naturalists have considered garnets as ores of tin, doubtless on account

account of their colour; they differ however from tin ores, by their transparency and their weight, which last is much less. Messrs. Bucquet and Sage have not found that they contain tin.

The different states of tin found in nature, are not therefore numerous, and may be reduced to the following varieties.

Varieties.

1. Native tin in leaves or plates.
2. White spathose tin ore, in octahedral crystals.
3. Tin ore of a yellowish white; often coloured and semi-transparent, like topazes. These two ores must not be confounded with the heavy stone, or tungsten of the Swedes, which we have described at the end of the salts, and has the property of becoming yellow by the nitrous and muriatic acids.
4. Brown or reddish tin ore, in cubical crystals, more or less regular.
5. Tin stone, tinberg of the Swedes; it is a stone or sand, which contains a mixture of calx of tin. The specimens are grey, blue, brown, and black.
6. Sulphureous ore of tin, of a brilliant colour, similar to that of zink, or golden, like aurum musivum.

To

To make the assay of an ore of tin, it must be grossly pounded, after dividing it into different parcels, washed and roasted in a covered capsule of earth, care being taken to uncover it from time to time, in order to dissipate the tin as little as possible; for if it be roasted in an open fire, much of that metal is lost, as Cramer remarks. It must likewise be roasted with expedition, lest the tin should be too much calcined. Mr. Baumé, to obviate these two inconveniences, proposes to mix a quantity of rosin or pitch, which reduces a portion of the calx formed in this operation. After the ore is roasted, it is to be quickly fused in the crucible, with three parts of black flux, and a small quantity of decrepitated marine salt. By comparing the weight of the ore with that of the metallic button obtained, the quantity of foreign matter, and the proportion of tin it will afford in the hundred, is known. Cramer proposes to make this assay in a more expeditious manner, and perhaps with less loss, by making use of two large pieces of charcoal; one of them must have a cavity, to serve instead of a crucible, into which the ore is put, with a sufficient quantity of pitch. The other is perforated with a small opening, to give issue to the vapours. This is applied on the former to cover it, and they are tied together with iron wire, after having luted the joinings. These are set on

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means of charcoal placed round them. As soon as a sufficient heat has been given to fuse the tin, the charcoal is to be extinguished with water, and the tin is found within them, in the form of a button or globule.

Bergman proposes to assay the ores of tin by solution in vitriolic acid, to which the muriatic acid is afterwards added; and to precipitate it by fixed alkali. If the tin be pure, one hundred and thirty-one grains of the precipitate will be equal to one hundred and six of tin. If it be mixed with copper and iron, these foreign metals are to be removed by means of the nitrous and muriatic acids.

The working of ores of tin in the large way, is similar to the process before described; it is often necessary to make fires of wood in the mine, to calcine and soften the gangue, which is very hard, by which very dangerous vapours are disengaged. This process is used in the mines of Geyer. In other places the ores are found in sand, at a very small depth, as at Ebenstock. The pounded ore is washed in boxes, with little partitions of cloth, to retain the metallic particles; it is then roasted in reverberatory furnaces, to which a horizontal chimney is adapted, to collect the sulphur and arsenic; after which it is fused, and poured into moulds, to give it the form of blocks. The ores of tin are wrought nearly in the same way in Germany and in England. In the

the latter country, this metal is alloyed with lead and copper, according to Geoffroy, and never exported in a state of purity. We likewise receive from England, a kind of tin in stalactites, which is called grain tin, which is thought to be very pure; but Messrs. Bayen and Charlard affirm, that it sometimes contains copper. The purest tin of all is that which comes from Malacca and Banca; the first has been run into moulds, which give it the form of a quadrangular truncated pyramid, with a narrow slope round its base, each ingot weighs about a pound. The second is in oblong ingots, weighing forty-five or fifty pounds; these two kinds of tin are covered with a grey rust, more or less thick.

The tin which comes from England, and is much more used than the pure tin of the Indies, its price being lower, is in the form of large blocks, of about three hundred pounds weight. It is alloyed with copper, either artificially, according to Geoffroy, or naturally, according to Baron Dietrich. To facilitate the sale, it is afterwards melted into small ingots, or sticks, of nine or ten lines in circumference, and about a foot and a half long.*

* English tin being the most generally used, on account of its plenty, is the most generally adulterated by the foreign venders. It is a vulgar error among foreigners, that pure tin is not permitted to be exported hence. According to Neumann, every tin founder in Holland has English stamps, and whatever his tin may be, the inscription block tin makes it pass.

Tin exposed to heat in close vessels, melts very quickly. It is the most fusible of metals, and remains fixed as long as the fire is not raised; but this fixity appears to be only relative, since a considerable heat volatilizes it, as we shall shortly observe. It is to be heated with access of air; its surface becomes covered with a dull greyish pellicle. When this is taken away, the tin is seen underneath with all its metallic brilliancy. A new pellicle soon becomes collected, and in this manner all the tin may be reduced into pellicles, which are nothing else but a metallic calx, or combination of the metal with the base of vital air. Tin becomes one tenth heavier by calcination. If the metal be heated to redness, Geoffroy has observed, that its calx is gradually raised by a very lively whitish flame, which he compares to that of zink. This is a true inflammation, or rapid combustion of the metal, at the same time that a light fume of tin is volatilized, which is condensed on cold bodies, into a whitish calx, in the form of needles or flowers of tin. The grey calx of tin becomes white, if again exposed to the action of a strong fire; it unites to an additional quantity of the oxygenous principle, and becomes more calcined. In this state it is called putty. If it be exposed to an exceedingly strong heat, as for example, that of a porcelain furnace, it melts into

into glass. Messrs. Macquer and Baumé have observed, that tin thus treated in a crucible, is converted into a white and needle-formed calx, or flowers of tin, and the part underneath is hard, coherent, reddish, and imperfectly melted calx; that another part forms a glass of the colour of a ruby or hyacinth; and that lastly, at the bottom of the crucible a part of the tin remains in the metallic state. Calx of tin requires a fire of the utmost violence to melt it into glass; the calx or putty may be decomposed by the addition of animal or vegetable combustible matters, which seize the oxygenous principle contained in the calx, and cause the metal to re-appear with all its properties. It seems, however, that well calcined putty strongly retains the base of air to which it is united, since it is not reduced but with great difficulty, and by the addition of a large quantity of combustible matter. Hence it is, that Messrs. Baumé and other chemists have concluded, that when tin ores are too much roasted, a portion is converted into a calx no longer reducible into metal.

Tin is not much altered by exposure to air, and does not readily become tarnished when it is pure. The tin of commerce is covered, after a certain time, with a grey powder, which, according to Macquer, is merely superficial, and never penetrates into

the metal, as the rust of copper and iron does.

Water does not dissolve or calcine tin, though in process of time it tarnishes its surface.

Earthy matters contract no union with this metal. Its calx, which is very infusible, does not form a transparent, nor coloured glass with vitrifying substances; but as it is exceedingly white, it renders the glass of a very opaque white colour, by its interposition between the transparent parts. This kind of vitreous frit is called enamel. Putty of tin, on account of its infusibility, deprives all glasses of their transparency, and converts them into coloured enamels.

The action of lime, magnesia, and alkalies on tin, has not been inquired into. It cannot, however, be doubted, but the latter salts are capable of producing some change in the metal, since in a very short time they cause it to exhibit the colours of the rainbow.

The concentrated vitriolic acid, or oil of vitriol, according to Kunckel, dissolves half its weight of tin. The solution is performed very well by the assistance of heat. Sulphureous gas, of a very penetrating smell, is disengaged, without any apparent effervescence or motion. The tin, in this experiment, seizes the oxygenous principle of the vitriolic acid, becomes quickly calcined, and the oil of vitriol is found to contain a sufficient

ficient quantity of the calx, to afford a precipitate by the addition of water. Oil of vitriol diluted with a small quantity of water acts likewise on tin, but the solution is more permanent, and affords a less abundant precipitate on the addition of more water. Spirit of vitriol, or feeble vitriolic acid, does not dissolve it. In this combination the tin seizes the oxygenous principle of the oil of vitriol, in such quantities, that sulphur is very suddenly formed. This substance gives the solution a brown colour while it is warm, and is precipitated as soon as it becomes cold. Messrs. Macquer and Baumé have ascertained the presence of sulphur in this combination. When the solution is more strongly heated, the tin is precipitated in the form of a white calx. The same phenomenon takes place without the assistance of heat, though in a much longer time.

Tin dissolved in the vitriolic acid, is very caustic. Mr. Monnet, by cooling, obtained crystals similar to selenite, or fine needles, intermixed with each other. The calx of tin precipitated from its solution by standing, or by heat, is soluble in the vitriolic acid. If the vitriolic solution of tin be evaporated to dryness, the calx it affords is of a grey colour, very difficult of reduction, and no longer soluble in the acid. Alkalies precipitate tin from the vitriolic acid, in the form of a very white calx.

Nitrous acid is decomposed by tin, with a singular degree of rapidity. Heat is not necessary to promote this solution, which is one of the most rapid and striking among chemical phenomena. It appears, that the tin has a very strong tendency to unite with the oxygenous principle of the nitrous acid; and as nitrous gas is far from adhering as strongly to the pure oxygenous principle in this acid, as sulphur to the same principle in the acid of vitriol, it is not surprising that the decomposition of the former, by tin, should be much quicker than that of the latter, by the same metal. A large quantity of very strong nitrous gas is disengaged with the greatest rapidity. I have observed, that this combination constitutes one of the most advantageous methods, of instantly obtaining a large quantity of this gas. The tin is converted into a white powder or calx, which Macquer in vain attempted to reduce. The metal in this state appears to be supersaturated with the oxygenous principle. The nitrous acid holds but a very small quantity of the metal in solution; and when evaporated with the intention of obtaining crystals, the dissolved portion quickly precipitates, and the acid remains nearly in a state of purity. Bucquet however affirms, that a nitre of tin, whose form he has not determined, may be obtained from this solution; it is very deliquescent,

deliquescent. He likewise asserts, that if the calx of tin, produced by the decomposition of the nitrous acid, be washed with water, the fluid dissolves a small quantity of nitre of tin, which may be obtained by evaporation. The nitrous acid retains a somewhat larger quantity of tin in solution, when it is used in a very diluted state; but it lets it fall by standing, or by the application of heat. Messrs. Bayen and Charland, in their valuable inquiries concerning tin, have discovered, that when the nitrous acid is charged with all the tin it can calcine, so as to become thick and incapable of acting on new portions of the metal, a nitrous salt is obtained, by washing the mass with a large quantity of distilled water, and evaporating the water to dryness, which salt detonates alone in a heated vessel, and burns with a white and dense flame, like that of phosphorus. The calx of tin well washed, affords when dry, a semi-transparent mass, resembling scales. The stanonitrous salt distilled in a retort, swells up, boils, and instantly fills the receiver with a white thick vapour, of a nitrous smell.

The fuming muriatic acid acts strongly on tin, and dissolves it by the help of a gentle heat, and even in the cold; instantly losing its colour and property of emitting fumes. The very slight effervescence which takes place in this combination, disengages
a fetid

a fetid gas from the mixture, not at all resembling the smell of arsenic, as some chemists have affirmed. The muriatic acid dissolves more than half its weight of tin; the solution is yellowish, of a very fetid smell, and does not afford a spontaneous precipitate like the two last mentioned acids. By evaporation it affords brilliant and very regularly formed needles, which slightly attract the humidity of the air. Mr. Monnet affirms, that these needles, after having deliquiated, crystallize, and remain dry in the air. M. Baumé, who prepared the muriate of tin in the large way, as for example, in the proportion of one hundred and fifty pounds of acid to twenty-five pounds of tin, for the manufacture of painted silks, has accurately described some of its properties. Out of two pounds of tin dissolved in forty-eight pounds of muriatic acid, there remained two ounces six drachms of a grey powder, not soluble in one pound of the acid, with which he digested it for several days. Margraff takes it to be arsenic, but M. Baumé did not examine it. He compares the smell of this concentrated solution to that of the black earths taken out of old sewers, and remarks, that when it touches the fingers, nothing can take away the metallic smell peculiar to tin, which it communicates to them, and which is not dissipated in less than twenty-four hours. He observes, that
the

the crystals of the muriate of tin vary according to the state of the acid. In some cases they form small white needles; and the same solution as afforded him white and rose coloured crystals. The latter, purified by solution and evaporation, afforded, by cooling, large crystals, nearly similar to those of the vitriol of soda. Another time, when the common muriatic acid was used, he obtained the salt in the form of small scales, of a pearly white, similar to that of sedative salt. He does not speak of the action of fire on this salt. Mr. Monnet, who distilled the muriatic solution of tin, affirms that he obtained a fat matter, very fusible, and readily congealing, and afterwards a true butter of tin, with a fuming liquor similar to that of Libavius, hereafter to be mentioned. This fact agrees with the observation made by Macquer on a solution of tin in the muriatic acid, which crystallized almost totally during the winter, and recovered its fluidity in summer; a property likewise observable in butter of tin. This illustrious chemist remarked, that a white deposition subsided at the end of some years. The combination of the muriatic acid and tin, affords a much more abundant precipitate than other solutions, on the addition of alkalies and lime. Alkalies re-dissolve a part of the precipitated calx, and assume a yellow brown colour. It was by dissolving a variety

riety of specimens of impure tin in this acid, that Messrs. Bayen and Charlard succeeded in discovering a small proportion of regulus of arsenic in the English tin. When this semi-metal is contained in tin, the action of the acid produces a black colour in the metal, and when the solution is finished, a blackish powder remains, which is arsenic, either pure, or united to a small quantity of copper. This acid therefore may be used to discover the presence and quantity of regulus of arsenic contained in tin.

The dephlogisticated muriatic acid, dissolves tin very readily, and without sensible effervescence, because that metal quickly absorbs the super-abundant oxygenous principle from the acid, and does not require any decomposition of the acid to effect its own calcination. The solution has then all the characters of the preceding.

Aqua regia, made with two parts of nitrous acid, and one of muriatic acid, dissolves tin with effervescence. A strong heat is excited, which must be checked by plunging the mixture into cold water. To form a permanent solution of tin in aqua regia, the metal must be added by small portions at a time; one portion being suffered intirely to disappear, before a succeeding one be added; if the whole were added at once, great part of the metal would be calcined. Aqua regia, by this management, will dissolve

solve half its weight of tin. The solution is of a reddish brown, nearly transparent, and frequently, in a few seconds, becomes converted into a tremulous jelly, of the appearance of rosin. This substance becomes more solid at the end of a few days, and may be cut in pieces like a firm animal jelly. Some parts exhibit the semi-transparency and whiteness of the opal. It emits a penetrating smell of marine acid, but is not fetid like the muriatic solution. I have preserved it several years in a bottle, imperfectly closed, and found that it has not lost any part of its solidity or transparency. In order that the solution of tin, by aqua regia, may form a jelly, it must be charged with a large proportion of metal. Sometimes it becomes concrete, on the addition of half its weight of water, though it was perfectly fluid before: but the jelly formed by the addition of water, is of an opal colour, because, according to the remark of Macquer, the solution itself being decomposable by water, a portion of the calx of tin is precipitated, and destroys the transparency of the jelly. This learned chemist has likewise observed, that if a solution of tin in aqua regia be heated, an effervescence is excited, which arises from the re-action of the mixed acid on the metal, its whole action not being already exhausted. The solution then loses all its colour, and becomes fixed by cooling.

The

The jelly it forms in this case, is beautifully transparent. Small needle-formed crystals are frequently deposited from a regaline and liquid solution of tin by standing. Neither these, nor the gas disengaged during the action of aqua regia on tin, have been yet examined. Messrs. Bayen and Charlard find, that this solvent might likewise be used to discover the presence of regulus of arsenic in tin, if its action on the semi-metal were less considerable. But this circumstance prevents its indicating the quantity with the same precision as the muriatic acid.

The action of other acids on tin is not known.

All the neutral vitriolic salts, and especially vitriolated tartar and Glauber's salt, are decomposed by tin. Equal parts of vitriolated tartar and tin being heated in a crucible, afforded me a greenish melted mass, which no longer exhibited any metal, and was a true liver of tin. The tin deprives the vitriolic acid of its oxygenous principle, the sulphur formed by this decomposition, becomes hepatic by the action of the alkali, and this hepar dissolves a portion of the calx of tin. It is the third metallic substance, in which we have observed this property of decomposing alkaline vitriols. We shall presently find, that Glauber made the same observation on the ammoniacal vitriol.

This

This metal causes nitre to detonate with rapidity. For this purpose it is melted, and made obscurely red hot in a crucible. Common nitre in powder being then thrown in, produces a white and brilliant flame. The tin, when the addition of nitre no longer produces detonation, is intirely calcined. The white powder which remains, contains alkali, rendered caustic by the calx of tin, and united to a certain quantity of that calx. By lixiviation, and the addition of an acid, the tin may be precipitated. The grey calx of tin is fusible with nitre, because, as Geoffroy has observed, it contains a portion of tin, which is only in a state of extreme division. If a perfect calx of this metal be taken, as for example, such as has been long heated, and is very white; or instead thereof, such a calx as is afforded by acids, the same phenomenon does not follow.

Tin very readily decomposes ammoniacal muriate, and disengages a very caustic and gaseous volatile alkali. Bucquet, who made a course of experiments on the decomposition of sal-ammoniac by metallic substances and their calces, observes, that much inflammable gas is disengaged by the re-action of tin on the marine acid. According to the experiments of this learned chemist, metals decompose this salt, by virtue of the action of the muriatic acid on them: and as we
have

have seen, that the marine acid has a very strong affinity with tin, it may be concluded, that the theory of Bucquet is satisfactory and perfectly consonant with the facts. Glauber informs us, that his secret sal ammoniac, or ammonical vitriol, is decomposed by tin; but this decomposition is not complete, according to Pott, who repeated Glauber's experiment; doubtless because the vitriolic acid has not so strong an affinity with tin as the muriatic. But he likewise observes, that the tin being very fusible, is collected in a button at the bottom of the retort, and that consequently, the ammonical muriate is not so completely decomposed as otherwise it might be by the metal. For this reason tin does not decompose this salt as perfectly as less fusible metals. The residue of the decomposition is a corneous tin or butter of tin, decomposable by water, and similar to that which is formed by this metal with corrosive sublimate, hereafter to be treated of.

Tin may be easily combined with sulphur, by throwing one or two parts of sulphur in powder, on five or six parts of tin melted in an iron ladle. The mixture being agitated with an iron spatula, becomes black, and takes fire. If it be melted in a crucible, a brittle mass, disposed in flat needles united together, is obtained. This combination is much more difficult to melt than tin, a
property

property common to all combinations of soft and fusible metals with sulphur. But the most important circumstance is, that though tin easily unites with sulphur by fusion, it is never found naturally in this state. The fact is absolutely the contrary with zink, which is frequently combined with sulphur in its ores, though it does not unite with it in our laboratories without the greatest difficulty. The operations of nature are often very different from those of art; but though some natural combinations are found, which art has not succeeded in imitating, it is likewise certain, that many compositions are artificially produced, of which nature furnishes no model.

Arsenic scarcely unites with tin by fusion, because the greater part is dissipated. The neutral arsenical salt combines better with that metal; and M. Baumé has observed, that in this combination, the arsenic quitting the alkali to unite with the tin, produces a brittle brilliant button, disposed in facets like the regulus of antimony. The experiments which Margraff has made concerning the union of tin with arsenic, by distillation, have shewn us, that part of the arsenic is reduced into the reguline form, while a portion of the tin is calcined. The tin thus united to arsenic, is not separable by the action of the most violent fire, and it is probable the former metal always retains

a portion of arsenic, sufficient to render its use dangerous in culinary operations. When the calx of tin, charged with arsenic, is exposed to distillation, a small quantity of liquid, which has the smell of phosphorus, is obtained, according to Margraff. Messrs. Bayen and Charlard have, since his time, examined the combination of arsenic and tin. They observe, that the calx of arsenic, called simply, arsenic, does not combine with tin, but in proportion as it acquires the metallic state; and that this combination is effected much better, by directly uniting the regulus of arsenic with tin. If three ounces six drachms of tin be put into a retort, with two drachms of regulus of arsenic in coarse powder, and the retort, after adapting a receiver, be heated to redness, scarcely two grains of arsenic are elevated in the neck of the vessel, and a metallic button, weighing four ounces, is found at the bottom of the retort. This alloy, which contains one sixteenth of its weight of regulus of arsenic, is crystallized in large facets, like bismuth. It is more brittle than zink, and less fusible than tin. It first becomes soft by heat, and if in this state it be touched with an iron rod, a crackling noise is produced by the friction of its laminæ on each other. It melts into the consistence of paste, and gradually emits the regulus of arsenic in the form of fumes.

Cobalt

Cobalt unites by fusion to tin, and forms an alloy in small close grains, of a light violet colour.

Tin and bismuth afford, according to Gellert, a brittle alloy, presenting cubic facets in its fracture. Tin is sometimes alloyed with this last metal, to give it whiteness and hardness. As it communicates a great degree of firmness, and is dearer than zink, which produces the same effects on tin, workmen cannot be supposed to employ it in a larger proportion than a pound, or a pound and a half in the hundred, in which case, its effects on the animal œconomy need not be feared. But in larger proportions they might be suspected to resemble those of lead, from the strong affinity between the properties of bismuth and that metal. Bismuth may be separated from tin by the marine acid, which dissolves the latter, and suffers the former to precipitate in a black powder, provided the acid be weak. Aqua regia, diluted with water, produces the same effect.

Regulus of antimony, united to this metal, affords, according to Gellert, a white and very brittle metal, whose specific gravity is less than that of the two metallic substances taken separately.

Zink unites perfectly with tin, and produces a hard metal of a close grained fracture,

ture, and more ductile in proportion as the quantity of tin is larger.

Cronstedt affirms, that nickel united to tin forms a white and brilliant mass, which when calcined under a muffle, rises in the form of a vegetation.

Mercury dissolves tin with great facility, and in all proportions. To make this combination, heated mercury is poured on melted tin; the amalgama produced, differs in its solidity according to the relative doses of these two metallic substances. An amalgam was formerly made with four parts of tin, and one of mercury, which were cast into balls that became solid in cooling; these balls were suspended in water for the purpose of purifying it: but as the water was at the same time made to boil, the precipitation of foreign substances, which contaminated the water, was intirely owing to the last circumstance, and not to the metallic substance. The amalgama of tin is capable of crystallizing, and has the form of small cubes, as Mr. Daubenton observed in the amalgam of tin used by him to close the mouths of vessels containing preparations in the King's garden. Mr. Sage affirms, that the crystals are grey, brilliant, and in plated laminæ, thin towards their edges, and that the cavities between them are polygonal.

Tin has a stronger affinity with the muriatic acid than mercury, and decomposes the
corrosive

corrosive mercurial muriate. To effect this, the tin is first divided by the addition of a small portion of mercury; equal parts of this amalgam, and the corrosive mercurial muriate are triturated together, and the mixture exposed to distillation in a glass retort, by a very gentle heat. A colourless liquor first passes over, and is followed by a thick white vapour, which issues with a kind of explosion, and covers the internal surface of the receiver with a very thin crust. The vapour becomes condensed into a transparent liquor, which continually emits a thick, white, and very abundant fume. It is called the fuming liquor of Libavius, and is the combination of the muriatic acid and tin, the acid appearing to be supersaturated with the oxyginous principle. This liquor, when closed in a bottle, does not emit visible vapours, though a certain quantity is disengaged, which deposits the calx of tin in needle-formed crystals, at the upper part of the bottle; so that the extremity of the neck becomes accurately closed at the end of some months. A small portion of this calx is likewise precipitated to the bottom of the liquor, in the form of regular scales. The smell of this fluid, which is very penetrating, excites coughing: the vapours are not visible without contact of air, and seem to consist of a peculiar gas, decomposable by air, which in that case deposits the calx of

tin, in the same manner as the sparry acid deposits quartzose earth by the contact of water, and as the hepatic gas of Bergman deposits sulphur by the contact of air. May not this elastic fluid be a combination of the dephlogisticated muriatic gas and calx of tin?

Water does not sensibly precipitate the fuming liquor of Libavius, but seems to effect a decomposition, which has not yet been properly examined. When this liquor, newly prepared, is poured into distilled water, it occasions a slight noise, resembling that of oil of vitriol, during its union with the same fluid. It appears to separate a great number of small transparent particles, of an irregular figure, which do not seem to have any affinity with water. On a closer attention to the mixture, each of these particles is observed to emit a bubble, which breaks at the surface of the water, and emits a vapour, which becomes white by the contact of air. On agitating the water, these particles are very quickly dissolved, and the solution no longer emits vapours. Macquer affirms, that when the fuming liquor of Libavius is diluted with a large quantity of water, it precipitates the calx of tin in small white flocks. The gas of the fuming liquor is not very elastic, as it never causes the stopper of the bottle, in which it is closed, to fly out, as happens occasionally

occasionally to the nitrous and marine acids, the volatile alkali, ether, &c.

The residue of the distillation of the fuming liquor of Libavius, exhibits phenomena equally interesting with those of the liquor itself. The upper part and the neck of the retort, are covered with a light, white and greyish crust, which, according to the experiments of Rouelle the younger, contains a small quantity of the fuming liquor, corneous tin, mercurius dulcis, and running mercury: the bottom of the vessel contains an amalgam of mercury and tin, above which is a corneous tin of a light grey, solid and compact, which may be volatilized by a stronger heat. If this substance be put into a retort, it melts, and is separated into two distinct substances, the one black, and lying beneath the other, which is white, and resembles corneous tin. The name of butter of tin might perhaps be applied more properly than that of corneous tin, to these combinations. Rouelle appears to suspect that these two substances, which differ from each other, and do not mix, arise from the tin being alloyed with some other metal; the more the tin is alloyed, the smaller the quantity of fuming liquor it affords, according to this skilful chemist. Corneous tin attracts the moisture of the air, and is easily soluble in water; which distinguishes it from corneous lead. M. Baumé has pub-

lished a theory respecting the combination of tin with the marine acid, which nearly resembles that of Scheele and Bergman, concerning the dephlogisticated marine acid. He thinks that this acid loses its phlogiston in the operation, as those chemists supposed likewise to happen in the distillation with calx of manganese. He suspects that this acid would be obtained perfectly pure, by distilling the fuming liquor of Libavius. Whence it appears that he regards the common marine acid as surcharged with phlogiston. M. Baumé has therefore, from this observation, the precedence in point of time over Mr. Scheele, for the discovery of the two states of the marine acid; but he has not described the singular properties of this acid, when it is supersaturated with air, as the celebrated Swedish chemist has done.

The uses of tin are very numerous. It is applied to many purposes in the arts, in forming many vessels, organ pipes, decorations, &c. Its amalgam is applied to silver looking-glasses. Coppersmiths pour a mixture of tin and lead on copper vessels, in the operation called tinning. Bell metal, and bronze for statues, are compounds of this metal, with copper. The pewterers mix tin with bismuth, regulus of antimony, lead and copper, to make utensils of all sorts, which are very little subject to change by exposure to air. Putty, or calx of tin,

is used in polishing many hard bodies. Tin is melted with calx of lead and sand, to make enamel, as well as to glaze pottery, &c. The crySTALLIZED muriate of tin is useful in the art of callico printing. Its solution in aqua regia, heightens the tincture of cochineal, of gum lac, &c. so as to convert it into the most lively fire colour. The dyers make use of this solution, which they call composition, to make scarlet. When it is mixed in the dyers bath, it forms a precipitate, which carries down the colouring matter, and deposits it on the stuff which is to be dyed. This observation is due to Macquer, whose labours have greatly improved this art.

The use of tin in culinary operations has been esteemed very dangerous by some chemists. Navier, in his treatise on counter poisons, &c. affirms, that ragouts, in which tin spoons have been left, as well as sugar contained in a vessel of this metal, have poisoned many persons. These unhappy effects have been almost generally attributed to the arsenic which Geoffroy, in the year 1738, affirmed to exist in tin, and which Margraff imagined he had found in the purest tin, even in a very considerable proportion.

But the fears which have been excited on this subject, are dissipated by the experiments of Messrs. Bayen and Charlard, whom

we

we have had already occasion to quote, in the history of this metal. These chemists proved, by the most decisive experiments,

1. That the quantity of arsenic, extracted by Margraff, from the tin of Morlaix, and which is near thirty-six grains per half ounce, would be much more than sufficient to deprive this metal of all the softness and flexibility it is known to possess, and would render it as brittle as zink.
2. That the tin of Banca, and of Malacca, does not contain an atom of this dangerous semi-metal.
3. That English tin, in large blocks, affords by the action of muriatic acid, a small quantity of blackish powder, often mixed with copper and arsenic, in which the latter never exceeds three quarters of a grain in the ounce of tin, and is often less than that quantity.
4. That the mixture made by the pewterers, of the English block tin, with the pure tin of Malacca, or Banca, diminishes this dose still more.
5. That regulus of arsenic, united with tin, loses a part of its properties, and its corrosive action.
6. Lastly, That the small quantity of tin thus alloyed, which may enter into food by the daily use of vessels made of this metal, is not sufficient to produce any effect on the animal œconomy, since, according to a calculation made on the loss a tin plate suffered during two years wear, the quantity swallowed at most does not amount

to

to three grains in the month, and consequently, the 5760th of a grain of regulus of arsenic per day; supposing that tin wrought at Paris, contained as much of this poisonous semi-metal, as the plate or dish made in London, on which Mr. Bayen made his experiments.

We will here observe, that the disagreement between the Parisian chemists and Margraff, may arise from the latter having made his experiments on Saxon tin, and the former on the tin used in France, which comes from the East-Indies and from England.

We may also observe, that many physicians, who have directed their attention to metallic substances, considered as medicines, have already acknowledged the innocence of this metal, and have even advised its filings to be taken in substance, in disorders of the liver, of the matrix, and for worms. Schulz, in his dissertation on the use of metallic vessels, in the preparation of food and medicines, recommends pure tin as very wholesome. La Poterie prescribes calx of tin as one of the component parts of a preparation called antihectic, which consists of a lixivium of calx of the regulus of antimony and tin, formed by detonation with nitre; the alkali, which the water dissolves, always retains a portion of the metallic calx.

Tin

Tin is recommended as a vermifuge. I have been informed that it has been employed in large doses at Edinburg, without effect. Some country people are in the habit of infusing sweet wine for four hours in the cold, in a tin vessel, and giving a glass of this liquor to their children, who are troubled with worms. Navier was a witness to a girl of sixteen or seventeen years old, who voided downwards thirty of the worms called teres, with plentiful stools, some hours after having taken a liquid of this kind; the medicine therefore acts as a violent purgative.

C H A P. XVI.

Concerning Lead.

LEAD is an imperfect metal, of a dull white, inclining to blue. The alchemists give it the name of Saturn. It is the least ductile, the least elastic, and the least sonorous of all the metals; it may be reduced into thin plates under the hammer, and does not harden by beating. No metallic substance has less tenacity. A wire of lead of one tenth of an inch in diameter, supports no more than twenty-nine pounds and a quarter, without breaking. It is the third metallic substance in the order of weight;

weight ; a cubic foot of lead weighing 828 pounds, and it loses in water between the eleventh and twelfth of its weight. It is very soft, and easily cut with a knife ; has a peculiar and remarkable smell, which becomes stronger by friction. Its taste is scarcely sensible in the mouth, but its effect is very manifest in the stomach and intestines, whose nerves it irritates, producing pain, convulsions, stupor, and palsy. It is susceptible of a regular form : the Abbé Mongez obtained quadrangular pyramids, lying on their sides, so that of the four faces, one always is much the largest. Each pyramid is composed as it were of layers, or zones of other small pyramids, commonly terminating in one single acute pyramid.

Lead is rarely found native ; Wallerius and Linnæus admit its existence in this state, but it is denied by Cronstedt, Justi, Monnet, &c. It is most commonly in the earthy, saline, or mineralized form, united with sulphur, and forming galena. The lead mines are commonly at considerable depths in the earth, and are situated both in mountains and in plains. Naturalists have distinguished a great number of ores of lead ; the most essential to be known are the following.

1. Native calx of lead. The spathose ores of lead must not be confounded with this calx, which contains the cretaceous acid.

acid. It does not effervesce with the nitrous acid, and is commonly in white, grey, ponderous solid masses, or mixed with clay, sand, and chalk. The colour of the clay accordingly, as it is more or less ferruginous, constitutes native massicot and minium. The native ceruse of lead is often found on the surface of galenas.

2. Cretaceous lead, or the combination of the calx of lead with the cretaceous acid; this varies greatly in colour: it is white, black, brown, yellow, or green, according to the state of the iron which alters it. It is in general called sparry lead ore, because it has the texture and crystallization of certain spars; it effervesces with the nitrous acid, which disengages the cretaceous. The following varieties of this species are distinguished.

Varieties.

A. White spathose lead ore. This is a calx of lead, slowly deposited by water, in a crystallized form: it has sometimes a semi-transparency, like spar; its crystals are usually hexahedral prisms, truncated, or in cylindrical striated columns, which appear to be composed of a great number of threads, or in small fine needles. It is sometimes found of a brilliant white, like the silky gypsum. Other specimens

specimens are of a yellowish white. Some of the prisms are often fistulous. The white spathose lead ore, abounds in Lower Britany, in the mines of Huelgoet and Poullaouen. Mr. Sage affirmed, that the white lead ore is mineralized by the muriatic acid. Mr. Laborie asserted, that it was a pure earth of lead, united to fixed air, or cretaceous acid, and crystallized by water. The Academy of Paris, having caused the experiments of these two chemists to be repeated, adopted the opinion of Mr. Laborie; and Macquer has related the transaction in his Dictionary, at the article Ores of lead. The spathose lead ore is sometimes found in the same places as the galena, and seems to be a decomposition of that ore which has lost its sulphur, and whose lead is in a calcined state; for it is not rare to find galenas, which are passing to the state of white lead, as Mr. Romé de Lisle has well observed.

- B. Some naturalists have admitted a black ore of lead. It is white lead altered by an hepatic vapour, and by that means is revived. It may be considered as a middle species, between
white

white lead and galena, and is either crystallized, or in irregular masses.

C. The green spathose lead. This mineral is of a green, more or less transparent; often yellowish, always mixed with ochre and iron clay. It is sometimes without any regular form, and resembles a kind of moss. Such are most of the specimens from the mines of Hofgrund, near Freyberg in Brisgaw. Green lead ore is commonly crystallized in hexahedral prisms, truncated, or terminated by hexahedral pyramids, either intire or truncated near their base. It is found in great plenty at St. Marie-aux-Mines, and at Tschoppau in Saxony. It is proved that it owes its green colour to the mixture of iron, since it is always found in mines of that metal.

D. Spathose lead ore of the colour of peach blossoms. Mr. Mongez found this variety crystallized like white spathose lead, in the mines of Huelgoet.

E. Yellow spathose lead ore. This variety crystallized in hexahedral transparent laminæ, has not been known till within a few years. The laminæ are from half a line, to four or five lines

lines in diameter : they resemble glass of lead.

3. M. Monnet has discovered lead combined with the vitriolic acid. It is commonly in the form of a white mass, soluble in eighteen parts of water. Sometimes it is blackish, crystallized in very long striæ, or in friable stalactites : this last variety effloresces in the air, and becomes converted into a true vitriol of lead. On account of this effervescence it is that M. Monnet calls it pyritous ore of lead. Dr. Withering affirms, that there exists in the Isle of Anglesea, a large quantity of lead and iron mineralized together by the vitriolic acid.

4. Lead appears to be combined with the arsenical acid, in the red lead ore of Siberia, of which Mr. Lehman first gave a description, in the year 1766. This ore is of a very beautiful red, and its powder resembles carmine : it is often crystallized in rhomboidal tetrahedral pyramids, short and obliquely truncated. M. Mongez, who thinks that arsenic exists in its acid state, in all the red ores of lead, has discovered another ore of a greenish yellow from Siberia, and containing arsenic like the following.

5. M. Gahn discovered the phosphoric acid in a greenish lead ore. There is likewise a yellow and reddish ore of this kind. If this be dissolved in nitrous acid, and the calx of lead precipitated by the vitriolic

acid, the phosphoric acid may be obtained by evaporation of the supernatant liquor. Messrs. Metherie and Tenant have confirmed the analysis of M. Gahn, by experiments made at Paris.

6. Lead is most commonly found combined with sulphur. This ore is named galena; it is likewise called alquifoux in commerce. It is composed in general of laminæ, which have nearly the colour and aspect of lead, but it is more brilliant, and very brittle. A great number of varieties of galena have been discovered, viz.

Varieties.

- A. Cubic galena. Its cubes, which are of various sizes, are found either single or in groups; it is often found with the angles truncated, and is common at Freyberg.
- B. Galena in masses. This has no regular configuration; it is very common at St. Marie.
- C. Galena with large facets. It does not seem to compose regular crystals; but it is intirely formed of large laminæ.
- D. Galena with small facets. This appears to be formed like the mica, of small, white, and very brilliant scales; it is called white silver ore, because it contains a considerable quantity

quantity of that metal. The ore of the mines of Pompean in Britany, is of this kind.

E. Small grained galena; so called, because it has a very close grain. It is likewise very rich in silver, and is found with the foregoing ore. Galenas in general contain silver; none are known to be without it, except that of Carinthia; but it has been observed, that those galenas afford the most, whose facets or grains are the smallest. It seems as if silver, being in some measure a foreign substance in the combination of galena, prevented the regular crystallization of that ore.

F. Galena crystallized like lead spar, in hexagonal prisms, or cylindrical columns; it is found as well as the foregoing, in the mines of Huelgoet in Lower Britany. It contains little silver, and seems to be merely spathose lead mineralized, without having lost its form. Crystals of pure spathose lead, intirely covered with a very fine galena, are sometimes found in the same piece, together with others which are absolutely changed into galena throughout. M. Romé de Lisle possesses many specimens of this kind. I

I have in my collection a specimen of white lead ore, the base of whose prisms is absolutely in the state of galena; which proves the change we are speaking of.

Galena is often found placed between two layers of blackish ochreous quartz, which contain much silver, though the metal is not apparent. M. De Dolomieu, the author of this observation, apprehends that lead was originally mixed with the silver; but that the water having carried off the imperfect metal, left the fine metal in the gangue. M. Monnet has discovered, that many galenas become vitriolized like pyrites. He affirms, that by washing one of these, whose surface was become white and efflorescent, he obtained a true vitriol of lead.

7. Lead is sometimes naturally united with sulphur, regulus of antimony, and silver. This ore, which is called antimoniated galena, is of a needled or striated structure, like antimony. The semi-metal is known by the white flowers which rise during calcination. It is found at Salberg, and at Saint Marie-aux-Mines.

8. There is another kind of galena, in which the lead is united to sulphur, silver, and iron. This martial galena is harder, and more solid than the foregoing. It affords

fords a yellow calx of lead during its scorification.

9. Lastly, calciform lead is often found, together with galena, in sandy or calcareous earths and stones.

As almost all the ores of lead, and especially the galenas, contain a considerable quantity of silver, it is proper to make a careful assay of their contents. For this purpose, after having pounded and washed a certain quantity of the mixed ore, it is roasted in a covered vessel, to prevent its being scattered by decrepitation. The galena does not lose much by the roasting. After it has passed this operation, it is weighed, and melted with three times its weight of black flux, and a small quantity of decrepitated marine salt. The fixed alkali of the black flux, absorbs the sulphur; the coal of the tartar, which is a part of the same flux, serves to reduce a portion of the metal which is in the calciform state; and the marine salt opposes the evaporation of part of the matter contained in the crucible. After the fusion, a button of lead is obtained, which is to be carefully weighed, and then calcined or vitrified, to separate the lead from the silver it contains. But this assay cannot be greatly depended on, because the alkali, which is used as a flux, forms with the sulphur of the galena a liver of sulphur, which

dissolves a portion of the lead. And it must also be considered, that in the large way, a reducing flux, so expensive as the black flux, cannot be used. It is therefore more advisable, to endeavour to melt the ore among the charcoal, in a reverberatory furnace, or alone, with the addition of some cheap matter, to absorb the sulphur, such as a small quantity of iron, and glass gall.

Bergman proposes to assay lead ores by the nitrous acid. This acid dissolves lead, and calcines iron, but does not affect sulphur. The solution is precipitated by the cretaceous soda, and 132 grains of precipitate represent 100 grains of lead in its metallic state. If these ores contain silver, the calx of this metal is separated by the volatile alkali, which dissolves it.

At Pompean, the lead ore which contains silver is heaped up, washed with great care on tables, and carried to the furnace, where it is first roasted by a gentle heat, and afterwards melted by raising the fire. The melted lead is taken out of the furnace by a hole which answers to one of the sides of its hearth, and which had been closed with clay. The lead is then cast into pigs, which contain silver. To separate this precious metal, the lead is carried into another furnace, whose hearth is covered with ashes, well washed, sifted, and rammed down. On one of the sides of the hearth of this furnace,

nace, are placed two large bellows, opposite to which are two gutters, which are called the passages of the litharge. When the furnace is hot, the lead is calcined; part evaporates, and is sublimed in small chimnies which are over the passages of the litharge. Another portion of the metal is absorbed by the bottom of the furnace; a third part, which is the most considerable, is calcined, and even partly vitrified; this is called litharge. The bellows drive it out of the furnace, and likewise facilitate the calcination and vitrification of the lead, by the quantity of air they blow on the surface of the metal in fusion. When the litharge has been calcined by a moderate fire, it is in the form of a red scaly powder, which is called litharge of gold, on account of its colour. If the litharge has been more heated, and is in a more vitrified state, and of a pale colour, it is called litharge of silver. Lastly, when the furnace is heated strongly, so as to melt the litharge completely, and to fuse it in the form of irregular stalactites, it is called fresh litharge. When the operation is finished, the silver contained in the lead remains in the furnace. This silver requires to be again refined, but in smaller masses, in order that the remaining lead it still contains may be separated.

The lead which has been calcined in this operation of testing, is afterwards melted in contact with charcoal, and contains scarcely any silver: it is then cast into pigs, and exposed to sale. Spathose lead melts, in contact with charcoal, in the same manner as the calces of lead.

Lead exposed to heat, melts long before it becomes ignited. The heat necessary to hold it in fusion is so inconsiderable, that the hand may be plunged in it when melted without pain: and in this state it does not burn vegetable substances. It is scarcely at all volatile, yet by a very strong heat it fumes, and is reduced into vapours, like the more fixed metals. If it be suffered to cool very slowly after being melted, and the melted portion be poured off from that which is become solid, it is found to be crystallized in quadrangular pyramids, which we have already described.

Lead melted with the contact of air, soon becomes covered with a grey and dull pellicle; this pellicle is carefully taken off, and reduced by agitation into a powder of a greenish grey, verging towards yellow. When separated by the sieve from the grains of lead with which it is mixed, and afterwards exposed to a more violent red heat, it becomes of a deep yellow, and in this state is named massicot. This last, slowly heated by a gentle fire, assumes a beautiful red colour,

lour, and is known by the name of minium. If mafficot be too strongly heated, it melts into glafs without affording minium.

Lead by calcination becomes heavier, by the quantity of about ten pounds in the hundred. It was this increafe of weight, produced in calcining lead, as well as the neceffity of air for the operation, which caused John Rey, a phyfician of Perigord, to fufpect, that air is fixed in this metal during the procefs. Dr. Priestley has fince confirmed the opinion of John Rey, by obtaining pure air from minium. The calx of lead, though highly coloured, eafily lofes this colour. If minium be heated rather too much, it becomes pale: if it more strongly be urged by heat, it melts, without addition, into a transparent glafs, fo fufible, that it penetrates the crucible, and efcape. But if one part of fand be added to three parts of calx of lead, the fand melts by the affiftance of the calx, into a beautiful amber coloured glafs. The colour of this glafs is not fo deep, and refembles that of the topaz, when two parts of the calx of lead and one of fand, or pulverized flint, are fufed together. A fimilar quantity of the calx of lead added to common glafs, does not alter its tranfparence, but gives it a greater degree of weight, and more efpecially a kind of unctuousnefs, which renders it capable of being cut and polished more eafily

easily without breaking. This glass is very proper to form achromatic lenses; but it is subject to veins, and to have a gelatinous aspect. The English call it flint glass; our workmen find great difficulty in selecting pieces of any considerable magnitude, exempt from striæ, in that which is imported from England. This great imperfection seems, in Macquer's opinion, to depend on the principles of the glass not being uniformly combined: for that purpose it is required, that it should be long held in fusion; but as the lead would by that means be dissipated, the flint glass would lose a part of its density and unctuousness, which are its chief merit.

Though all the phenomena of calcination and vitrification of lead prove, that this metal unites with great facility to the base of pure air, it is nevertheless one of those metallic matters which adheres the least forcibly with that principle, since it gives it out by the simple action of heat, as Dr. Priestley has shewn. If minium be strongly heated in a retort, vital air is obtained, and a portion of the calx is reduced into lead. All the calces, and even the glasses of lead, are easily decomposed by combustible bodies. For this purpose it is sufficient to mix them with charcoal, foot, grease, oil, or rosin, or in a word, any inflammable substance whatever, and to heat them for a certain time, in order to obtain a button of lead. This
metal

metal has therefore less affinity with pure air than many other metallic substances have. Though it resembles tin in some of its properties, it is absolutely opposite to it in its calcination and reduction. These phenomena prove still more our explanation of one of the causes of the affinity of composition, viz. that the degree of affinity of two bodies must not be estimated by the facility with which they combine, but by the difficulty experienced in disuniting them.

All the calces of lead, and especially minium, have the property of becoming charged with a certain quantity of cretaceous acid, when exposed to air. If therefore it be desired that a calx of lead should remain in a state of purity, it must be kept defended from the contact of air, or slightly calcined before it is used, in order to separate the cretaceous acid it may have absorbed.

Lead exposed to air tarnishes the more readily, accordingly as the air is damper. It contracts a white rust, which water carries off by little and little. This white powder is not a pure calx of lead, but is combined with the cretaceous acid of the atmosphere. The silver extracted from old lead, which has remained exposed for a long time to the atmosphere, shews that the lead, which was not deprived of its sil-

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ver at the time it was first used, has been partly calcined by the action of the atmospheric air; so that the silver which remained unaltered, is gradually augmented by degrees, in its proportion to the quantity of lead destroyed by the action of the atmosphere.

Lead is not altered by pure water, because its principles are not separated by that fluid: yet the internal parts of lead pipes which conduct water, are covered with a whitish crust, or a kind of ceruse, which doubtless is produced by the action of the different substances contained in the water on this metallic substance.

Lead does not unite with earthy matters, but in its calciform state.

The action of the salino-terrestrial substances, and caustic alkalies on lead, or its calces, are not known.

This metal is soluble in all the acids, but oil of vitriol does not attack it, except it be boiling, and the lead be in small pieces. In this process volatile sulphureous spirit and gas pass over. When most of the acid is decomposed, the mixture is white and dry, and separates into two portions, on being washed with distilled water. The most considerable part is insoluble in water, and is a calx of lead formed by the base of the air, which the metal has seized from the oil of vitriol during the time of the disengagement of the sulphureous gas. This calx may be melted
or

or reduced like that which is made by the combined action of fire and air: the portion dissolved by the water, is a combination of vitriolic acid and calx of lead. This solution, by evaporation, affords some needles of vitriol of lead. Messrs. Baumé and Bucquet have not spoken of this salt, but under that form. M. Monnet sometimes obtained it in prismatic short columns. M. Sage blames this chemist, because he affirms that he found vitriol of lead to afford crystals in tetrahedral prisms. It is a very caustic salt, and requires at least eighteen parts of water to dissolve it. It is decomposed by fire alone, and also by lime and alkalies.

The nitrous acid appears to act very strongly on lead. When this acid is well concentrated, the lead is quickly reduced into a white calx, by means of the oxygenous principle which is separated from the nitrous acid, at the same time that the nitrous gas is disengaged; but if the acid be more feeble, it is less decomposed, and a sufficient quantity remains to dissolve the calx of lead. During this solution a grey powder is precipitated, which Grosse took to be mercury; but M. Baumé affirms, that this matter is nothing but a portion of the calx of lead; and I have several times in vain attempted to obtain mercury by sublimation, and by urging this powder with

with a fire capable of reducing mercury, if it had been in the state of calx. This solution does not afford a precipitate on the addition of water. Its crystals obtained by cooling, are of an opake white, in the form of flat triangles, whose angles are truncated. The same solution, by a slow evaporation of several months, afforded crystals, the largest of which was one inch in thickness, of the form of hexahedral pyramids, whose three faces are alternately large and small, and whose point is truncated, so that each crystal is an eight sided solid. Rouelle has described this salt very well. The nitre of lead decrepitates in the fire, and melts with a yellowish flame when laid on an ignited charcoal. The calx, which is at first yellow, becomes quickly reduced into globules of lead. This salt is decomposable by lime and alkalies. The vitriolic acid, though it acts but feebly on lead, has nevertheless a stronger affinity to that metal than the nitrous acid. If pure vitriolic acid, or any neutral, earthy, or alkaline vitriolic salt be added to a nitrous solution of lead, a white precipitate is formed in a very short time: this precipitation takes place, because the vitriolic acid seizing the calx of lead, forms with it vitriol of lead, similar to that which is prepared by the immediate combination of the vitriolic acid with that metal.

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The pure muriatic acid, by the assistance of heat, calcines lead, and dissolves part of its calx; but it is difficult to saturate it completely. This solution always has an excess of acid, but nevertheless affords, by a strong evaporation, crystals in the form of fine and brilliant needles, as M. Monnet has observed. The muriate of lead is scarcely at all deliquescent. Lime and alkalies decompose it like the vitriol of lead. This metal becomes more readily and intimately combined with the muriatic acid, by adding the acid itself, or the acid united with an alkaline or earthy base, to a solution of nitre of lead. A white precipitate is immediately formed, which is much more abundant than that produced by the vitriolic acid, and resembles a coagulum. It is a combination of the calx of lead with the muriatic acid, which has separated the metal from the nitre. This salt falls down, because it is much less soluble in water than nitre of lead; if it be exposed to heat, it gives out vapours, whose taste resembles sugar, and melts into a brown mass, called corneous lead, because it partly resembles the silver which is distinguished by the same name; it is soluble in thirty times its weight of boiling water. The solution of this salt, by evaporation, crystallizes into small, fine, and brilliant needles, which form bundles, or unite by one of their extremities

tremities in an obtuse angle. Mr. Sage affirms, that this solution affords, by insensible evaporation, crystals in striated hexahedral prisms. The solution of corneous lead is decomposable by the vitriolic acid, which occasions a precipitate resembling that before obtained from the solution of nitrous acid. This discovery, due to Grosse, has been verified by Baumé; it detects an error in the eighth column of the table of affinities of Geoffroy, which asserts, that lead has a stronger affinity with the muriatic acid than with the other mineral acid.

All the solutions of lead are precipitated of a black or brown colour by liver of sulphur; a kind of galena being formed by the transition of the sulphur to the calx of lead, which seems to shew that lead is in the calciform state in that ore. In these experiments a double decomposition takes place, without a double elective attraction, because the saline base of the hepar would decompose the vitriol, the nitre, and the muriate of lead, without any other addition.

All the calces of lead are soluble in acids as readily as lead itself, and often with greater facility. Minium loses its colour in these solutions. Lead does not act on the vitriolic neutral salts, neither does it decompose vitriolated tartar by heat, as tin, zink, and regulus of antimony do.

Lead does not sensibly detonate with nitre. When this neutral salt in powder
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is thrown on the melted metal in a low red heat, it excites scarcely any commotion or apparent flame, though the lead is calcined and vitrified by the alkali of nitre, and takes the form of small yellowish scales, similar to litharge.

Lead decomposes sal-ammoniac very well by the assistance of heat. This property is common to many of the metals. The calces of lead triturated with this salt, disengage the alkaline gas in the cold; but if the mixture be heated in a retort, the decomposition is very rapid, and a volatile, caustic, and very penetrating alkaline spirit comes over. Some chemists have affirmed, that the volatile alkali obtained by minium, effervesces with acids, and have thence concluded, that minium contains cretaceous acid. But Bucquet has observed, that this effervescence is produced by a portion of alkaline gas, volatilized by the heat produced during the combination of the alkali and the acid, and that it only takes place when concentrated acids are used. He has made very ingenious and decisive experiments on this subject. After having introduced into a glass vessel over mercury, volatile alkaline spirit, obtained by means of minium, he added a sufficient quantity of vitriolic acid, somewhat concentrated, for the saturation of the alkali. The ebullition, or disengagement of gas, was immediately excited,

which was quickly after absorbed, and consisted of alkaline gas. The mass which remains in the retort after the decomposition of sal-ammoniac by minium, is muriate of lead, which melts by a moderate heat into corneous lead, and is totally soluble in water. This mass was employed by Margraff, in the process for making the phosphorus of urine.

Inflammable gas very sensibly affects lead, by producing changeable colours of the rainbow on its surface, and revivifying its calces. Minium, in contact with this gas, becomes black, and of a leaden colour. Dr. Priestly has observed, that a tube of glass, containing inflammable gas, sealed hermetically, and exposed several days to the heat of a sand bath, was intirely covered on its inner surface with a black tinge, and that a vacuum, with drops of water, was formed in the tube. This valuable experiment is explained by the greater affinity which the inflammable principle has to the oxygenous principle, or base of air, than lead has; and this is likewise proved by the total incapacity of that metal to decompose water. English glass contains a large proportion of calx of lead. The inflammable gas acted on this calx, and by degrees deprived it of its oxygenous principle, with which it formed drops of water; the lead

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at the same time assuming the metallic colour.

Sulphur readily unites with this metal. When these two substances are melted together, a brittle compound is produced, of a plated texture, and a deep grey brilliant colour. This matter, which nearly resembles galena, is much more difficult to melt than lead; a phenomenon peculiar to the combinations of certain metals with sulphur. Those which are very fusible, become more difficult of fusion when united to that substance, while such as are difficultly fused, acquire a great degree of fusibility by this addition.

The alloy of lead with arsenic has not been examined. Nickel, manganese, cobalt, and zinc, do not unite with lead by fusion; regulus of antimony forms a brittle alloy with some brilliant facets, similar in texture and colour to iron or steel, according to the proportions of the mixture, and of a specific gravity, more considerable than the two metallic substances, separately taken, would compose.

Lead combines with bismuth, and affords a metal of a fine and close grain, which is very brittle. Mercury dissolves lead with the greatest facility; this amalgam is made, by pouring hot mercury into melted lead. It is white and brilliant, and becomes solid at the end of a certain time. When tritu-

rated with the amalgam of bismuth, it becomes as fluid as running mercury. It is proper to observe, that this singular phenomenon takes place in the union of three very fusible ponderous, and more or less volatile, metallic matters.

Lead unites very easily by fusion with tin. Two parts of lead and one of tin, form an alloy more fusible than either of the metals taken separately, and constitutes the solder of the plumbers. Eight parts of bismuth, five of lead, and three of tin, compose an alloy so fusible, that the heat of boiling water is sufficient to melt it, as Mr. Darcet has discovered.

The alloy of lead with tin being employed frequently in economical uses, and the first of these metals being capable of rendering utensils made with the second very dangerous for culinary or pharmaceutical purposes, it is an inquiry of considerable importance, to ascertain the proportion of lead, which very often amounts to more than the public regulations permit. Messrs. Bayen and Charlard have described an excellent process for determining the quantity of this vile and dangerous metal contained in pewter, or other compounds of tin. It consists in dissolving two ounces of the suspected metal, in five ounces of a good pure nitrous acid. The calx of tin is to be washed

washed with four pounds of distilled water, and dried, and the water evaporated by the heat of a water bath. By this evaporation nitre of lead is afforded; which being calcined, the weight of the residue shews the quantity of that metal contained in the tin, allowing a few grains for the augmentation of weight arising from calcination, as well as the other metallic substances, such as zink and copper, which the tin under examination may contain. These chemists, by this method ascertained, that fine wrought tin or pewter contains about ten pounds of lead in the hundred, and that the common tin, sold in France under that name, often contains twenty-five pounds in the same quantity; an enormous dose, sufficient to expose those who use vessels made of this composition to the greatest danger. Lead is almost constantly a part of the vessels continually used, such as measures for distributing fluids, more especially wine. It scarcely need be observed, that a liquid, which quickly becomes acid, may unite with lead, and may convey into the viscera of those unfortunate persons who drink it, the seeds of disorders so much the more dangerous, as their cause is not suspected.

The pewterers have several methods of discovering the fineness of tin, and the quantity of lead it contains: simple inspection often answers their purpose; and the

weight and the noise produced in bending, greatly assists their judgment. They have two kinds of assay: the one called assay by the stone, which consists in pouring the melted tin into an hemispheric cavity, hollowed in a thunder stone, terminated by a channel. The phenomena which the tin exhibits in its cooling, its colour, the roundness of its surface, the depression of its middle part, the noise which the tail of the assay bent backwards and forwards produces, are the chief signs which the intelligent workman takes notice of, and by long observation applies with considerable accuracy, to ascertain the fineness of the metal. But this assay used by the master pewterers at Paris, does not appear to be so exact as the other practised by the masters in the country, though rejected with disdain by the former. This second assay is called by the ball or medal, because it consists in pouring the tin intended to be assayed, into a mould, which gives it the form of a ball, or a flat mass similar to a medal. The weight of this sample is compared with a similar volume of fine tin poured into the same mould; the more the tin under examination exceeds that of the specimen in weight, the more it is alloyed with lead. Messrs. Bayen and Charlard with great reason prefer this last assay, the principles of which are more certain, than the circumstances

stances on which the workman, who uses the assay of the stone, must ground his judgment.

Lead is used in a great number of works. It forms a part of many alloys, and is made into pipes for the conveyance of water. Its calces are employed in glass-making, and in the preparation of enamels. It is used to imitate the colour of yellow precious stones, and to give fusibility to the glaze of earthen ware. Utensils and vessels proper for economical uses are made with this metal, but not without danger in their use, as we have before observed. Fountains, or vessels of lead, in which water is suffered to remain a long time, often communicate a noxious quality to it. Its vapour is dangerous to the workmen who melt it, and its taste is still more dangerous to such as file and scrape it. This metal, lodged in certain parts of the stomach and intestines, produces violent cholics, often accompanied with vomiting a very brown bile, and characterized by the flatness of the belly, and sinking of the navel. It has been observed, that in such cases, antimonial emetics and purges have been attended with great success. Navier advises the different livers of sulphur, in cases of poisoning by the preparations of lead, as well as in such as are produced of arsenic and corrosive sublimate; and it is more particularly in the

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palsy and tremblings, which commonly remain after the painters cholic, that this physician boasts of the good effects of liver of sulphur and hepatic waters. At all events, when these facts are duly considered, we ought to avoid the internal use of preparations of lead, and only apply it as an external medicine; and even in this last case, it ought not to be administered, but with all that care and caution which are required in the use of a strong repellent.

C H A P. XVII.

Concerning Iron.

IRON, called Mars by the alchemists, is an imperfect metal, of a white livid colour, inclining to grey, internally composed of small facets. It is susceptible of a very beautiful and brilliant polish, and its hardness and elasticity are such, that it is capable of destroying the aggregation of all the other metals.

Iron has a considerable smell, especially when rubbed or heated. It likewise has a very evident styptic taste, which acts strongly on the animal economy. Next after tin, it is the lightest of metallic substances; a cubical foot of this metal, when forged, weighs 580 pounds. It may be extended into
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plates by beating, but as it is very hard, and becomes still harder under the hammer, it cannot be made into leaves. Its ductility, when drawn into wire, is much more considerable; very fine wires being made of this substance for musical purposes: this property appears to depend on its tenacity. In fact, iron is the most tenacious of all metals, except gold. An iron wire of one tenth of an inch in diameter, sustains a weight of 450 pounds without breaking.

Pure iron has a peculiar crystalline form. In the furnaces, where the metal has been suffered to cool slowly, quadrangular, articulated, and branching prisms, formed of octahedrons, implanted one in the other, were found. This observation was made by Mr. Grignon, master of the forges at Bayard, in Champagne. Lastly, besides all the properties which iron partakes in common with every other metallic substance, it presents three which are peculiar to itself. The first is magnetism, or the property of being attracted by the magnet, and of itself becoming a very good magnet, either by remaining a long time in an erect position, or in the direction from south to north; or by serving as the conductor to the electric fire of thunder, as many facts attest; or by being strongly rubbed against another piece of iron. The second property is that of taking fire, or suddenly melting by the stroke
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of a flint; a phenomenon to which the poets universally attribute the discovery of fire by the first men. The third property which distinguishes it, is, that it is the only metallic substance which is found in plants and animals, whose fluids it partly colours. It is likewise probable, that these organic beings themselves form this metal: for such plants as grow in pure water, contain iron, which may be extracted from their ashes.

Iron is a metal which is very abundant in nature; since, independent of that which plants and animals contain, it is found in almost all coloured stones, bitumens, and in almost all metallic ores. But we shall, in this place, attend only to the mineral substances which contain it in such large quantities, as to be worth extracting. In these ores, which are very numerous, iron is either in the metallic or calciform state, or else mineralized by different substances.

I. Native iron is known by its colour and malleability. It is very rare, and is only found occasionally in iron mines. Margraff found it in a fibrous form at Eibenstein in Saxony. D. Pallas discovered in Siberia, a mass of 1600 pounds; and Mr. Adanson affirms, that it is common at Senegal. Some naturalists think, that these native specimens of iron are produced by art, and

and have been buried in the earth by accidents.

2. Iron exists very often, more or less calcined, in the form of rust. It is distinguished into rich and poor, fusible and refractory iron. The rich iron is not much rusted, and contains only a very small quantity of earth. Fusible iron is that which melts easily, and affords cast iron of a good quality. The metal is united in its ore to several fusible stones. Dry or refractory iron is calcined, and mixed with infusible substances. All the bog ores of iron are commonly disposed in beds, in the manner of stones, and seem to have been deposited by waters. It is very often in the form of spherical bodies, either flat or irregular. Organic matters, such as wood, leaves, bark, shells, &c. are not unfrequently found in the state of bog ores. This kind of conversion or transition, seems to indicate a sort of analogy between this metal and organic substances. In the wood of Bologne, near Autueil, there is a mine of bog ore of iron, in which vegetable substances become mineralized, almost immediately under our eyes.

3. The eagle stones, or ætites, is a variety of the bog ore; they are bodies of different forms, commonly oval or polygynous, composed of concentric layers, disposed round a nucleus, which is frequently moveable

able in the centre of the stone. The drying and shrinking of these layers, forms a middle cavity, in which several fragments, more or less considerable, exist loose, or detached. This stone has received the name it bears, because it was formerly thought that the eagles deposit it in their nest, and that it has the property of facilitating births. Hence it has been concluded, that this stone acts strongly on the fœtus in utero. Some authors have even affirmed, that it was possible to accelerate the labour of women, by tying the eagle stone to their leg, or to retard it by tying it to their arm.

4. The hematites are a sort of muddy iron ore, which seem to be formed in the manner of stalactites; its name comes from its colour, which is commonly red, or of a blood colour, though this colour is subject to variations. The hematitis is usually composed of layers which cover each other, and are themselves formed of convergent needles; the external part of this ore is covered with tubicles; it is not only distinguished by the colour, but by the form. Such are the hematites in needles found in Lorrain; the tuberclated hematites are in the form of bunches of grapes, or the hematites botrytes, &c. These ores are often found together with the muddy iron ore, and are deposited on a variety of different bodies.

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5. The loadstone is a muddy iron ore, which some persons however imagine to be very near the metallic state. It is known by its property of attracting steel filings, and is found in Auvergne, and in Biscay in Spain; the varieties are distinguished by their colours.

6. Emery, smyris, is a grey or reddish iron ore, which several mineralogists consider as a sort of hematites; it is very hard, is very refractory, and is abundantly found in the island of Jersey and Guernsey. It is reduced into powder, in mills, and in this state is used to polish glass and metals.

7. Spathose iron ore, is a calx of iron combined with the cretaceous acid; and worn by water; it is usually of a white colour, though all the shades of grey, yellow, and red, are found. It is always disposed in laminæ of different thickness, semi-transparent like spar; is heavy, and often regularly crystallized. Considerable quarries of this ore, frequently mixed with pyrites, are wrought; as that of Allevard in Dauphiny. Sometimes it is mixed with grey silver ore, as the iron of Baigorri; or with manganese, as that of Styria. Some mineralogists think, that it is a spar in which the metallic calx has been deposited. Spathose iron ore is decomposed without addition, in close vessels, and affords cretaceous acid; the iron remaining in a
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black powder, is strongly attracted by the magnet, and easily melts by the action of a considerable heat.

8. Nature likewise presents iron in the saline state, united to the vitriolic acid, and forming martial vitriol, or green copperas. This vitriol is found in the galleries of iron mines, especially those that contain pyrites; it is sometimes found in green crystals, or in the form of fine stalactites; and at other times it is not so pure. When it has lost the water of its crystallization, it is of a white or greenish colour; if it has suffered a calcination rather strong, it is yellow; and if the calcination be carried on still farther, a considerable portion of acid of vitriol will be obtained, and it is called natural colcothar, or chalcites. If mixed with certain inflammable matters, this salt is called melantari, on account of its black colour; all these different matters have received the name of lapides atramentarii, because like the vitriol of iron, they are proper to make ink.

9. Iron is often found united to sulphur, and then constitutes martial pyrites. This kind of ore has received the name of pyrites, because it is sufficiently hard to give numerous sparks when struck with the steel. The martial pyrites are commonly in small red masses, sometimes regularly formed; they are usually spherical, cubical, or dodecahedral, but their form varies considerably,

bly, as may be seen by consulting the Pyritologia of Henckel. Some are brown on the outside, and of the colour of iron; others are yellowish, and considerably resembling copper ores, even at their surface. All are yellow, and as it were coppery, within, and for the most part are composed of needles, or pyramids of several sides, whose summits converge towards a common centre. The pyrites are commonly dispersed, and particularly in copper mines, in the neighbourhood of iron mines and in clays, and coal mines. The upper stratum of the latter is almost always pyritous. All the several kinds of pyrites are easily decomposed. A slight degree of heat is sufficient to deprive them of their sulphur. They are almost always spontaneously changed, when exposed to the air, especially in a moist place. They swell, burst, lose their brilliancy, and become covered with an efflorescence of a greenish white, which is martial vitriol. It seems that this alteration, which is called vitriolization of the pyrites, depends on the united action of air and water on the sulphur. Vitriolic acid is thus formed, which dissolves the iron, and rises above the surface of the pyrites like a kind of vegetation, which gradually separates the small pyramids which compose this mineral. All pyrites do not effloresce with the same facility. The globular pyrites, whose colour is very pale, and texture close,

close, become vitriolized very quickly. The others, which are of a brilliant yellow, or of the colour of copper, and are formed of small laminæ, very evenly applied on each other, do not effloresce but with great difficulty, and must be very carefully distinguished from the foregoing, because they differ from them in colour and texture, and other properties.

10. Iron is found combined with arsenic, both being in the metallic state. This ore, which is the true mispickel, is white, brilliant, granulated, or in facets, and does not contain sulphur, as the arsenical pyrites, properly so called, does. Wolfram was formerly considered as an arsenical iron ore, but it is now known to be an ore of Tungsten.

11. Black iron ore is known by its colour, by its property of being more or less attracted by the loadstone, and by being not at all soluble in acids. This iron is sometimes crystallized in the form of polyhedrons, or in rounded laminæ, and presents different spots of very brilliant rainbow colours: such is that of the Island of Elba. This iron forms a very considerable mountain, from which it is dug at the surface. The Swedish iron ore is likewise black, but is not crystallized. It is in masses more or less solid, mixed with quartz, spar, asbestos, &c. it is often hard enough to take a polish, at its

its surface appears as it were composed of specular, for which reason it, as well as the preceding, is called specular iron ore. It is found united in quarries of very considerable extent. This ore varies in its colour; when it is perfectly black, it is strongly attracted by the magnet; the blueish is less attracted, and the grey scarcely at all. The iron of Norway is likewise black, but it is commonly in small scales, like mica, often mixed with garnet and schorl. Black iron ore has sometimes the form of grains. It is likewise crystallized in calces, which has caused it to be denominated by some naturalists, galena of iron, or eisen-glants. When the micaceous ore of iron is black, it is called eisen-man, especially if the scales be very large. When they are red, and the powder which covers them is of the same colour, it has the name of eisen-ram. Iron ore in very regular, black octahedral crystals, and dispersed on a kind of shistus, or hard steatites, which comes from Sweden, Corfica, &c. appears to belong to this class. It is attracted by the magnet, and is very brittle.

Though the different kinds of iron ore, considered in this article, seem to have a strong analogy with each other; several mineralogists have considered them as very different, and have arranged them accordingly. This variety of opinions arises from

the exact knowledge of their nature not being yet obtained. It seems, that among those ores, there are some more or less approaching to the metallic state, as the octahedral iron ore of Corsica, and of Sweden, which M. Mongez compares to the martial *Æthiops*. This is strongly attracted by the magnet. Others, on the contrary, approach more to the state of calx, as the iron of the Isle of Elba, and especially the *eisenman*, and *eisenram*, which are not acted on by the magnet.

12. Iron is sometimes found in the form of a blue powder, of a more or less deep colour. In this state it is called native Prussian blue. It is mixed with vegetable earths, and especially with turf.

13. It has been discovered some years ago, that iron is often naturally united with an animal acid, known by the name of the phosphoric acid. The muddy or bog ores are sometimes of this nature; a portion of this compound remaining in the iron, gives it the property of being brittle when cold. Bergman, who was acquainted with this state of iron, without having determined its nature, called it *fiderite*; several other chemists have since called it water iron. We shall hereafter explain the method of separating this salt of cold short iron.

14. Lastly, Iron being the most abundant of all the metals, is frequently found mixed with

with sand, clay, chalk, and is the colouring matter of a great number of different earths and stones.

Iron ores are assayed after the following manner, by the dry way. After reducing them into powder, they are mixed with double their weight of pounded glass, one part of calcined borax, and a small quantity of charcoal in powder; the mixture is exactly triturated, and put into a crucible; a small quantity of marine salt is added, the crucible is then covered, and the heat raised to melting. When the mass is very slowly cooled, iron, more or less malleable, and in a small spherical button, often crystallized at its surface, is found.

Bergman proposes to assay iron ores by the humid way. He used the muriatic acid to dissolve the iron, and precipitated it by a portion of alkali. If other matters were mixed with the iron, he calcined them, and separated them by the nitrous and acetic acids, and afterwards dissolved the iron by the muriatic acid.

The treatment of iron ores varies, according to the state in which the metal is found. There are some ores which require no preparation before the smelting; others require to be pounded and washed, and some to be roasted, in order that they may become more friable and fusible.

The bog ores and spathose iron ore, are examined in the same manner, by smelting them with charcoal. The furnaces in which iron is melted, are of various heights, from twelve to fifteen feet; their cavity represents two quadrilateral pyramids, which join at their base about the middle of the height of the furnace. At the bottom of the furnace an aperture is made, from which the melted metal is to flow out; this aperture, which is closed with earth, corresponds with a triangular cavity, hollowed in sand, and intended to receive the melted iron. The process is begun by throwing some lighted brushwood into the furnace, and afterwards charcoal, with the ore, and certain fluxing matters; these are commonly of calcareous stone, with certain argillaceous stones, and sometimes quartz and flints. The stones, the charcoal, and the ore, are alternately thrown into the furnace, observing to cover the whole with a bed of charcoal, which must rise to the upper opening of the furnace. The smelting is performed by the help of two strong pair of bellows; and the iron melts passing through the charcoal, which reduces it. The stony matters added to the ore, becoming melted and vitrified, facilitate the fusion of the iron, which begins at the narrowest part of the furnace. The melted metal is collected at
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the bottom, and by opening the anterior aperture of the furnace, it is suffered to run out into the cavity in the sand; it is then called crude iron. A vitreous matter called slag, passes after the iron, and consists of the stones added to facilitate the fusion. Its colour is green, whitish, or blue, which it receives from a portion of the calx of the iron. The metal, thus obtained, has not the least ductility. Metallurgists are not agreed concerning the cause of this property of cast iron. Some think that it is owing to a portion of the vitreous matter; others attribute it to part of the calx of iron not being reduced. Brandt supposed it to arise from arsenic, and Mr. Sage thinks that it is produced by zink. Bucquet considered cast iron as iron not well reduced, and still containing a portion of metallic calx interposed between its parts. Bergman, who made many experiments on iron, has proved, that the brittleness of cast iron depends on a certain quantity of foreign matter, which he supposed to be a peculiar substance, and called siderite. It has been since discovered, that siderite is a compound of iron and phosphoric acid, and that it is likewise found in some kinds of malleable iron, as we shall hereafter shew.

Metallurgists distinguish several kinds of cast iron, white, grey, black, &c. That

which is of a grey brown, with blackish spots, is called speckled iron. The white cast iron is of the worst quality, and approaches to the character of semi-metals; the grey is of an intermediate quality between the first; and the black is the best, and affords iron of a good quality.

The cast iron is carried to be refined in a forge furnace, with a hearth rather hollow, in which a mass of cast iron, covered with a considerable quantity of charcoal, is placed, and the fire is urged by bellows, till the iron begins to soften. When it is in this state, it is repeatedly stirred, in order that it may present a larger surface, that the portion of iron which is in the state of calx may be reduced. The metal by this operation is likewise deprived of a portion of siderite which remained in it. It is next carried to the hammer, to be wrought into the form of bars. The hammering, by bringing the parts of iron nearer together, facilitates the separation of the siderite, and the portion of calx which the metal still contained, and by that means completes what was left defective by the fusion. This heating and hammering is repeated a number of times, till the iron has acquired the desired degree of perfection.

Two kinds of forged iron are distinguished; soft iron and steel. Steel is the best, the hardest, the finest, and the closest grained iron. Soft iron

iron approaches to steel in its qualities; its grain however is not so close, and when it is broken by bending backwards and forwards, it draws out, and appears to be composed of fibres. This fibre, or nerve, however, is only produced by the manner of breaking, and does not appear at all when the softest iron is broken short and suddenly; at the same time that iron of the worst quality will appear fibrous, if it be broken slowly and cautiously. The quality of iron may be estimated much better from its grain than from its fibres. Brittle iron has a large grain, which appears as if formed of small scales. It is distinguished into hot short iron, and cold short iron. The cause of this brittleness is at present known: the hot short iron contains much more siderite than other iron, and the quantity of this martial phosphoric salt is less and less in other iron, to the softest, which contains none at all. In order to separate this salt from iron, and to determine its quality, the metal is dissolved in spirit of vitriol, and a white precipitate, consisting of siderite, subsides gradually, which is collected and weighed.

Steel formed by forging, is scarcely ever perfect, and is besides in small quantity: but iron may be converted into steel by artificial means. For that purpose short bars of iron are inclosed in an earthen box or vessel, filled with a cement, commonly com-

posed of very combustible matters, such as soot, or animal oil, to which is usually added, ashes, calcined bones, marine salt, and sal-ammoniac. The box being well closed, is heated for ten or twelve hours, till the bars become white, and are ready to melt. In this operation the iron becomes purified, and is completely reduced by the assistance of the combustible matters with which it is surrounded; the portions, which were not perfectly in the metallic state, assume that state; and the siderite is intirely decomposed. As to the saline and earthy matters which were added, is not well known, whether they are of any advantage to the process. Steel prepared in this manner is called cemented steel, and appears to be iron in the purest state.*

Steel

* At the time of this part of his work going to press, the Ingenious author does not seem to have been in possession of the third volume of Bergman's opuscula, as he certainly would not in that case have retained the doctrine of Macquer, respecting the nature of steel. Steel is found to consist of iron in an intermediate state between cast iron and iron which is soft, tough, and malleable. The iron run from some German ores is found to be good steel, when forged only to a certain point. Cast iron, as Reaumur discovered, may be brought by cementation with animal ashes, into a state resembling steel, and by a longer continuation of the process, it resembles forged iron. This management, however, is less effectual than the usual method, probably because the impurities of cast iron are not removed by it. The chief differences in iron, as Bergman, in his admirable treatise, de Analyfi Ferri, teaches us, appear to depend on the presence or absence of plumbago. When cast iron

Steel may be converted again into iron, by cementation with calcareous earth and lime, which appear to be proper substances to calcine part of it.

It is evident that all the preparations to which iron is subjected, are necessary only, because that metal being more difficult to fuse than the others, is never perfectly purified by a single fusion.

There are some iron ores, particularly the black iron ore, as for example, that of the Island of Elba, in which this metal is so abundant, and so little altered, that nothing more is necessary than to melt it. It is sufficient if these be softened under the coal in the refining furnace, and conveyed from thence to the hammer. This is called the Catalan method, and can only be used with ores that contain but a small quantity of such foreign matter as are capable of being converted into scorix.

Spathose iron ores afford an iron so pure and so soft, that they are commonly called steel ores.

iron is dissolved in the vitriolic acid, the undissolved residue is found to consist chiefly of this mineral. Steel in the same circumstances affords less plumbago, and tough malleable iron leaves scarcely any residue. It follows therefore, that cast iron consists of the metal combined with plumbago, which is a kind of sulphur: steel is a more perfect iron, nearly as malleable in its soft state as forged iron; but in its hard state, as brittle as crude cast iron. Pure forged iron is the metal itself alone. T.

The

The chemical properties of iron are very numerous, and in order that they may be the more perfectly understood, we shall consider them as they exist in the purest steel.

Steel exposed to a less heat than ignition, assumes several shades of colour. It becomes successively white, yellow, orange, red, violet, and lastly blue, which colour remains a considerable time; but if the heat be raised, it changes to a disagreeable water colour. Steel strongly heated becomes red and sparkling, afterwards appears of the colour of strawberries; and lastly, very white and dazzling; it burns with a sensible flame. It does not melt but by an extreme heat. When thrown in filings in the midst of a burning fire, or even through the flame of a taper, it suddenly takes fire, and produces very brilliant sparkles. These are similar to those produced by the stroke of the steel against flint, and if collected on a white paper, they are found to be metallic, and resemble a kind of scoriæ. Common iron exposed to the focus of the lens of M. De Trudaine, suddenly throws out inflamed and burning sparkles. Macquer, who melted steel and iron in this lens, observed, that steel was the most fusible, which no doubt arises from the purity and homogeneity of this metal. Iron melted and suffered to cool slowly, takes a peculiar crystalline form, as we have already observed. M.
Mongez

Mongez described it to be a pyramid, or three or four sides.

The blow pipe, with vital air, causes the filings of iron to burn as rapidly as the focus of the lens of the Garden de l'Infant. If an iron wire turned in a spiral form, and terminated by a small piece of lighted quick match, be plunged into a vessel of vital air, the metal suddenly catches fire, and burns with a very remarkable degree of rapidity and deflagration. Steel, though very hard and refractory, is very easily calcined; when it begins to grow red, it combines with the base of air, and burns without any apparent flame at that heat. A bar of iron kept red hot for a long time, becomes covered with scales, which may be beat off with the hammer. In these however, the metal is only partly calcined, since they are attractable by the magnet. A more perfect calx of iron is made, by exposing filings of steel to heat under a muffle, when they become converted into a powder of a reddish brown, not attractable by the magnet, which is called astringent saffron of Mars. This martial calx differs according to the state of the iron, and the degree of calcination it has been subjected to. Some astringent saffrons of Mars are of a yellow brown, others the colour of a chocolate brown, and others of a beautiful red, similar to carmine. The astringent saffron of Mars, exposed to a very strong heat, melts

melts into a blackish porous glass, which is partly reduced by slowly heating in close vessels. If it has been a short time exposed to the air, it gives out a certain quantity of cretaceous acid during its reduction, which shews that it attracts this acid from the atmosphere. All the calces of iron have this character, in a greater or less degree; we have already pointed it out in the case of lead, in which the property is much more eminent.

The astringent saffron of Mars is easily reduced with combustible matters. When mixed with a small quantity of oil, and slowly heated in a crucible, it becomes black, and is strongly attracted by the magnet. This process affords a very good kind of martial *Æthiops*.

The purest iron exposed to moist air, soon loses its metallic brilliancy, becomes covered with a pulverulent yellowish crust, of a lighter colour than the astringent saffron of Mars. This matter is usually called rust. Common iron is much more subject to rust than steel; the more this metal is divided, the more rapid is its alteration by exposure to air. In this manner the preparation, known in pharmacy under the name of aperitive saffron of Mars, is prepared. Steel filings are exposed to the air, and moistened with water, by which means they very quickly rust. The same process with

with iron in the state of *Æthiops*, is still more expeditious. In this alteration the metal is agglutinated, and forms masses which must be levigated before they can be employed in medicine. It was formerly thought that the rust of iron was produced by the air, but it is at present known, that this metal is calcined by water. My own experiments lead me to think, that the aperitive saffron of Mars is a combination of the calx of iron with the cretaceous acid. I have distilled the saffron of Mars in the pneumato-chemical apparatus, and obtained a large quantity of cretaceous acid. The iron was changed into a black powder, strongly attracted by the magnet. M. Joffe, apothecary at Paris, has communicated to the Royal Society of medicine, a like process for quickly obtaining the martial *Æthiops*. He recommends igniting the aperitive saffron of Mars in a retort, to which a receiver, pierced with a small hole, is adapted without luting; by this means the heat disengages the cretaceous acid which Mr. Joffe suffers to escape by the opening in the retort, and the iron remains pure. I have often caused the pure vegetable alkali to crystallize by this means; the inside of the receiver being previously melted with a solution of that salt: for the cretaceous acid of the iron, together with the caustic vegetable alkali, forms that kind of neutral salt,

salt, which I have called chalk of pot-ash. I have made many other experiments on the rust of iron, which are explained in one of my memoirs. (*Memoires et Observations de Chimie*, 1784.) and various experiments have convinced me that this matter is a true neutral salt, formed of the calx of iron and cretaceous acid; for which reason I have given it the name of martial chalk, to distinguish it from the true calx of the metal. This salt is absolutely the same with that which Bergman calls aerated iron. This theory possesses the advantage of having been adopted by Macquer, and perfectly explains the cause why iron rusts very quickly in a humid and impure air; why it becomes rusted so quickly, and to such a depth, in places where the air is vitiated by the respiration of animals, by combustion, by animal vapours, and in stables, necessary houses, &c. Iron is the most alterable, by contact of air, of all metallic substances; and this alteration is not confined to its surface; bars of iron of considerable thickness, are often found to be rusted quite to the middle.

Cold water has a considerable action on iron, dividing it, and even dissolving a part, according to the experiments of Mr. Monnet; the purer the iron, and the more air the water contains, the larger is the quantity taken up. When iron filings have been agitated for some time in water, the metal
appears

appears to be extremely divided, and the turbid water, after decantation, deposits a very black and subtle powder, called the martial *Æthiops* of Lemery. This powder must be carefully dried in a close vessel, by a mild heat, lest the contact of the air should rust it. The martial *Æthiops* is strongly attracted by the magnet, and is in the first stage of calcination by water. As this operation is very long and delicate, many chemists have endeavoured to render it more easy in the practice. Rouelle employed the *mouffoirs de la Garaye* for this preparation, and obtained a very fine *Æthiops* in much less time than the process of Lemery requires to afford it. I think that the process of Mr. Jossé, which is much more expeditious, may be advantageously substituted; and several other processes for preparing *Æthiops* mineral are related in the following pages.

Bars of steel heated, and suddenly plunged in cold water, acquire a very considerable degree of hardness, and become brittle; these qualities are so much the more eminent, in proportion as the steel was hotter, and the fluid in which it is plunged, colder. This operation is called tempering. The degrees of hardness of steel may be varied at pleasure; and it may likewise be easily deprived of its hardness, by heating it to the same degree it had before the tempering, and suffering it to cool gradually. This effect

effect of the water appears to consist in a change in the disposition of the parts of the steel produced by the sudden cooling, which impedes its crystallization. All metals are capable of acquiring hardness by the same process. But this quality is the more sensible, accordingly as the metal is less fusible; a property which iron possesses in a very low degree.

It has been discovered about two years, that a strong action is exerted between water and iron. M. Lavoisier having exposed iron with water in a glass vessel, over mercury, observed, that the iron became rusty, and the water was diminished in proportion as the elastic fluid was disengaged, which filled the superior part of the apparatus. This fluid was inflammable gas; the iron had increased in weight, and was calcined. M. Lavoisier suspected that water contains pure air, and that this substance being united to the iron, the inflammable gas, or other principles of the water, was disengaged in the same proportion. He afterwards, made the experiment, in conjunction with M. Meusnier, in a more decided manner, by introducing the vapour of water into a red hot gun barrel; he obtained a large quantity of inflammable gas; the inner part of the gun barrel became increased in bulk, and assumed a black, brittle, lamellated appearance, similar to the iron ore of the island of

of Elba. The metal was increased in weight, and the addition, together with the weight of inflammable gas, corresponded perfectly with that of the quantity of water destroyed. The portion of iron calcined in this experiment, was found separate from that which had not sustained the same alteration; it formed an interior cylinder, thicker, and of a texture colour, consistence, and form, very different from that of the external part. The heat of red hot iron is necessary, in order to succeed this experiment, because it singularly favours the separation of the principles of the water by the metal, for which reason, when the gun barrel is not well ignited, and the water does not pass in a strongly elastic state, inflammable gas is not disengaged, the water not being decomposed; a want of attention to this circumstance, has caused several philosophers, who did not sufficiently heat the iron, and introduced liquid water, to deny the decomposition of that fluid, though its analysis, accurately made by this experiment, is confirmed by the synthesis, as Messrs. Mongez and Lavoisier have demonstrated. There are many other circumstances, in which water is thus separated into its principles, and contribute to the production of many very important phenomena, as will be hereafter explained.

Iron, in its metallic state, does not unite to earthy and stony matters; but the calx of iron facilitates the vitrification of all sorts of stones, and colours them either green or brown. The colour communicated by the calces of iron, are exceedingly various, according to the peculiar state of the calces, which approach more or less to the metallic state. These calces have likewise the property of affording various degrees of consistence to earths, with which nature or art has mixed them, by the assistance of water.

Barytes, magnesia, and lime, have no evident action on iron.

The pure fixed alkalies, and the volatile alkali, when dissolved in water, act sensibly on this metal: after several days digestion the fluids become turbid, and afford a small quantity of *Æthiops*, which falls down; a certain quantity of inflammable gas being at the same time disengaged, as the chemists of Dijon have observed. This circumstance proves, that water contributes greatly to the effect.

Iron is soluble in all the acids. M. Monnet has observed, that oil of vitriol does not act on this metal, unless it be boiling. When this acid is distilled to dryness from iron, the retort is found to contain flowers of sulphur sublimed, and a white vitriolic mass, partly soluble in water, which, however,

ever, does not afford crystals, because it has been decomposed by heat. If the vitriolic acid, diluted with two parts of water, be poured on iron filings, it dissolves the metal very readily, without the assistance of external heat. The solution is attended with the disengagement of a large quantity of inflammable gas, which may be made to detonate with a considerable noise, by applying a lighted candle to the aperture of the vessel, after having closed it for a short time with the hand. The inflammable gas burns with a reddish flame, and very often exhibits small sparkles, similar to those of iron filings. Macquer supposed, that the vitriolic acid in this combination disengaged a large quantity of phlogiston from the iron, and that the inflammable gas was derived intirely from the metal. This opinion appears to be founded on a circumstance formerly believed, viz. that inflammable gas might be extracted from iron alone, without addition, by the simple action of heat; but it is now proved, that iron does not afford inflammable gas by heat, but in proportion to the water or the moisture which may be present; and it is equally proved, that the water added to the vitriolic acid in the present experiment, is the only substance which produces the inflammable gas by its decomposition. 1. Because the vitriolic acid, in a concentrated state, affords

only sulphureous gas. 2. In the concentrated state, it does not attack iron, without difficulty, and by the assistance of a strong heat. 3. As soon as water is added, the action becomes much more rapid, and the production of inflammable gas takes place. 4. The quantity of concentrated vitriolic acid employed, is partly decomposed by the iron when water is not added; whereas, the acid intirely combines with the calx of iron, without suffering any decomposition when water is added to the solution. It is therefore the water which calcines the iron in this operation, as M. De la Place long since suspected, and Messrs. Lavoisier and Meusnier have proved.

In proportion as the diluted vitriolic acid acts on the iron, a portion of the metal is precipitated in a black powder, which Stahl supposed to be sulphur, but M. Monnet found, on examination, to be martial *Æthiops*. The portion of black calx of iron produced by the water, appears to be superabundant to the saturation of the acid. When one part of the iron is combined with one part of the acid, though the latter be far from saturation, the solution ceases, and the metal is no longer acted on. M. Monnet, who made this observation, remarks, that when water is poured on the mixture, the action of the acid commences again; a phenomenon which arises from the water of the

the spirit of vitriol being absorbed by the martial vitriol already formed; and the portion of the acid, which is not yet saturated, having no power to act on the iron, till a new quantity of water begins the calcination of that metal. The vitriolic acid dissolves more than half its weight of iron, and the solution filtered and evaporated, affords, by cooling, a transparent salt, of a beautiful green colour, crystallized in rhomboids, called martial vitriol, or green copperas.

Martial vitriol is not made in the direct way, because it is abundantly afforded by nature, and is easily extracted by art from martial pyrites. The pyrites being exposed to air for a certain time, become decomposed by moisture; a white efflorescence appearing on their surface, which, by solution in water and crystallization, is found to be vitriol. This decomposition of pyrites, according to Stahl, depends on double affinities. Sulphur, a compound of phlogiston, and the vitriolic acid, is not decomposable by water, nor by iron alone; but when these substances are united, the iron seizes the phlogiston of the sulphur, its acid uniting to the water, and dissolving the metal. The pyrites, which are the least susceptible of efflorescence; as for example, those which are the most brilliant, being roasted to drive off a portion of the sulphur they contain, and

afterwards exposed to the air, readily effloresce. The vitriol is separated by washing, and the solution of this salt immediately deposits a certain quantity of iron, in the state of ochre, for which reason the fluid is not evaporated, for the purpose of obtaining crystals, till this precipitate has fallen. Modern chemists think, that in the vitriolization of the pyrites, the sulphur which is in a state of extreme division, combines with a portion of pure air, and forms oil of vitriol, which, being diluted by the vapours which float in the atmosphere, unites with heat to the iron, and dissolves it. The necessity of the contact of air for the efflorescence of pyrites, gives much force to this opinion; and the moisture, which greatly favours the vitriolization, acts in this case as it does in the direct solution of iron; this is the cause of the inflammable gas which is disengaged when the operation is made in a vacuum.

Martial vitriol is of an emerald green, and has a very strong astringent taste; it sometimes reddens syrup of violets, but this effect is not constant; its crystals contain, according to Kunkel and Monnet, more than half their weight of water; if it be heated briskly, it liquifies like all salts, which are more soluble in hot than in cold water; it becomes of a whitish grey by drying; if it be heated by a more violent fire,

fire, a portion of its acid escapes under the form of sulphureous gas, and the salt assumes a red colour, in which state it is named colcothar. Martial vitriol calcined to redness, attracts the humidity of the air very sensibly, on account of a portion of vitriolic acid it contains. Martial vitriol distilled in a retort placed in a reverberatory furnace, affords first, water slightly acid; and when the heat is very strong, the oil of vitriol passes over of a black colour, and exhaling a suffocating smell of sulphureous vitriolic acid. These characters depend on its being deprived of a part of its oxyginous principle which is fixed in the iron, according to the doctrine of the gases; towards the end of the operation, the acid which comes over, takes a concrete and crystalline form, and is distinguished by the name of glacial oil of vitriol. This experiment, described by Hellot, did not succeed with Baumé, though it is admitted as certain by most chemists. When glacial oil of vitriol is distilled in a small retort, it gives out sulphureous gas, and comes over white and fluid; its concrete state is therefore owing to the presence of this gas; it unites with water with noise and heat, sulphureous gas being at the same time disengaged. The fuming oil of vitriol of Noorthaussen is of this kind, and the concrete salt obtained from it by a gentle heat, of which I have given an ana-

lysis in a memoir, to be published among those of the Academy.

The residue of martial vitriol, after distillation, is red, and similar to colcothar. When washed with water, a white salt little known, and named salt of colcothar or fixed salt of vitriol, is separated; a red insipid earth, which is a pure calx of iron, and is called sweet earth of vitriol, remains behind.

Martial vitriol exposed to the air becomes yellowish, and covered with rust; the vital air being gradually absorbed, calcines the iron more and more, so that it cannot remain united with the vitriolic acid. The solution of martial vitriol exhibits the same phenomenon, by the contact of the atmosphere, and both may serve the purpose of an eudiometer. This salt is soluble in twice its weight in cold, or in a less quantity of hot water; but as soon as the water is saturated, it appears turbid, by a quantity of ochre which separates; the fluid being filtered, and suffered to cool, affords rhomboidal crystals, of a pale transparent green; the remaining fluid being again evaporated, affords a new quantity of crystals by cooling; and when all the crystals have been obtained, that the solution is capable of affording, a mother water, of a blackish green, or brown yellow, remains, which is no longer capable of crystallizing;
this

this being evaporated by a strong heat, and suffered to cool, appears to be a soft unctuous mass, strongly attracting the humidity of the air; when evaporated to dryness, it affords a greenish yellow powder. According to Monnet, the mother water of vitriol contains iron in the state of a perfect calx: this chemist ascertained the fact, by immediately dissolving, with the assistance of heat, a true calx of iron in the vitriolic acid; the solution was brown, and incapable of crystallizing.

The calx of iron may be separated from the mother water of vitriol, not only by the earth of alum, but likewise by copper and iron filings, which does not happen to perfect martial vitriol. A well charged solution of martial vitriol being exposed to the air, is converted, after a certain time, into vitriol mother water, similar to the foregoing, by attracting the oxygenous principle of the atmosphere.

Martial vitriol is decomposable by lime and alkalies: lime-water poured into a solution of this salt, forms a precipitate in flocks, of a deep olive green; a portion of this precipitate is redissolved in the lime-water, and communicates to it a reddish colour. I have communicated two Memoirs to the Academy, in the years 1777, and 1778, concerning the martial precipitate obtained by caustic and non-caustic alkalies, in which I have

have carefully described the phenomena of their precipitations, and the state of the iron in the different circumstances. I shall here relate the principal circumstances relative to vitriol. Caustic fixed alkali precipitates the vitriolic martial solution in flocks, of a deep green, which are dissolved again by the alkali, and form a kind of martial tincture, of a beautiful red; when less of the alkali is added, the precipitate may be collected, and a blackish *Æthiops* is obtained; if it be dried quickly in closed vessels, without these two precautions, the iron quickly becomes rusted, because it is very much divided and moist. The vegetable alkali saturated with the cretaceous acid, or chalk of pot-ash, forms a precipitate of a greenish white colour, not dissoluble in the alkali; this difference arises from the presence of the cretaceous acid, which seizes the iron, in proportion as itself is separated from the alkali by the vitriolic acid; the pure or caustic volatile alkali, separates from the solution of martial vitriol a precipitate of so deep a green, that it appears black; it is not soluble in the volatile alkali. By sudden drying, without the contact of the air, it may be obtained black, and obedient to the magnet. The precipitate formed by concrete volatile alkali, or ammoniacal chalk, is of a greenish grey: it is partly re-dissolved in the salt, and communicates a red colour; an event directly contrary to what happens when

when the precipitations are made by fixed alkali.

Vegetable astringent matters, such as nut-galls, fumac, husks of nuts, quinquina, cypress nuts, logwood, tea, &c. have the property of precipitating martial vitriol in a black fecula: this precipitate, which cannot be mistaken for iron, is so extremely divided, that it remains suspended in the fluid; the addition of gum arabic to the mixture, causes the iron to be permanently suspended, and forms a black fluid, known by the name of ink. It is not well decided what happens during this experiment. Macquer, Monnet, and most chemists, consider the precipitate of ink, as iron united to a principle of the nut-gall, which disengages it from the acid; they seem to think that this principle is in an oily state. M. Gioanetti, physician at Turin, has made many experiments on iron precipitated from its solutions by astringents. These inquiries, which are to be found in his Analysis of the waters of St. Vincent, shew, that the precipitate is not attracted by the loadstone; that it becomes attractable by heating in a well closed vessel; that it is soluble in acids, without effervescence; that these solutions do not become black on the addition of fresh galls, which shews that the iron is united to the astringent principle, and is in the state of a kind of neutral salt. In the third volume of the Elements of Chemistry,

Chemistry of the Academy of Dijon, there is a series of experiments on the vegetable astringent principle, which seem to assimilate this substance to acids; in fact it reddens blue vegetable colours, unites to alkalies, decomposes livers of sulphur, dissolves and appears to neutralize metals, decomposes all metallic solutions with particular phenomena; rises in distillation without being deprived of its action on metals, and presents a great number of other properties, concerning which, the order we have adopted will not permit us to enlarge.*

The decomposition of martial vitriol, by an alkali calcined with bullock's blood, is a phenomenon still more difficult to be understood than the action of the nut-gall on this salt; the precipitate obtained is of a beautiful blue colour, and insoluble in acids. This precipitate is called Prussian or Berlin blue, from the place of its discovery.

* The valuable researches of the Academicians of Dijon on the astringent principle well deserve to be perused and studied; they considerably add to the labours of Messrs. Macquer, Monnet, and Gioanetti, on this important subject; the subject is however far from being exhausted, and requires to be examined at large, especially with the intention of discovering the nature of this singular principle, which is formed in all vegetable astringent matters, and appears to be soluble in a great number of menstrua, such as water, acids, alkalies, oils, spirit of wine, æther, &c. See the *Elémens de Chimie, theorique & pratique*, etc. pour Servir aux cours publics de l'Académie de Dijon, tome 3. page 403 to 421. Note of the author.

Stahl

Stahl reports that a chemist, named Diesbach, having borrowed some fixed alkali from Dippel to precipitate a solution of cochineal, mixed with a small quantity of alum and martial vitriol, the latter gave him an alkali from which he had distilled his animal oil; the salt precipitated the solution of Diesbach of a blue colour. Dippel examined the cause of this precipitate, and by a less complicated process, prepared the Prussian blue, which was mentioned in the year 1710, in the publication of the Academy of Berlin, but without any detail respecting the operations. Several chemists laboured earnestly to produce the same, and succeeded. But it was not till the year 1724, that Woodward published, in the Philosophical Transactions, a process for preparing this colouring substance.

To form Prussian blue, four ounces of nitre fixed by tartar are mixed with an equal weight of dried ox's blood; this mixture is calcined in a crucible till it resembles coal, and no longer produces any flame; a sufficient quantity of water is then added to dissolve all the saline matter, which is called phlogisticated alkali, and is concentrated by evaporation; two ounces of martial vitriol, and four ounces of alum, are afterwards dissolved in a pint of water; the solution of these salts is mixed with the alkaline lixivium, a blueish precipitate

precipitate falls down, which is separated by the filter, and marine acid being poured on it, it immediately becomes of a more beautiful and deeper blue, and is to be then dried by a mild heat, or by exposure to the air.

Many chemists have, since the time of Woodward, attended to the theory and preparation of Prussian blue. With regard to its preparation, it is now known that a great number of substances are capable of communicating to the alkali the property of precipitating iron of a blue colour.

Geoffroy, in the Memoirs of the Academy for the year 1725, communicated this property to alkalis with all kinds of animal coals. M. Baumé affirms, that the phlogisticated alkali may likewise be prepared by the coals of vegetable substances, provided a stronger heat be used. Spielman made it with bitumens, and Brandt with foot. The manufactories of Prussian blue are become numerous, and each, as it seems, use different matters for their preparation. M. Baunach informs us, that in Germany, the nails, horn, and skins of oxen are used. All animal matters do not, however, appear proper to phlogistificate the alkali; they have in vain attempted to prepare it with the gall of the ox, by a process similar to that which is executed with the blood. I obtained only an alkali, with precipitated vitriol of a greenish white, and the
preci-

precipitate was entirely soluble in marine acid.

Chemists have differed greatly on the theory of Prussian blue. Brown and Geoffroy considered it as the phlogistic part of iron, developed by the lixivium of blood, and transferred to the earth of alum: the Abbé Menon imagined that it was the purest iron, disengaged from every foreign substance by the phlogisticated alkali: Macquer, in a Memoir which has justly deserved the name of master-piece from every chemist, and is inserted in the Memoirs of the Academy for the year 1752, has refuted the opinions of these authors; he thinks the Prussian blue consists of iron, combined with an excess of the inflammable principle afforded by the phlogisticated alkali, which this last obtained from the blood. He observes, 1. That Prussian blue, exposed to the fire, loses its colour, and becomes simple iron. 2. That this blue is not at all soluble in acids, however strong. 3. That alkalies are capable of dissolving the colouring matter of Prussian blue, and of becoming saturated therewith: for this purpose, an alkaline lixivium is to be heated on Prussian blue, till it ceases to discolour that pigment. This alkali, saturated with the colouring matter of Prussian blue, is found to be deprived of most of its properties; it is no longer caustic nor effervescent

fervescent with acids; among the earthy salts it decomposes only the barytic; it precipitates all metallic salts, and it seems that this decomposition takes place by virtue of a double affinity, that of the acid on the alkali, and that of the metallic calx on the colouring matter united to the salt. An alkali in this manner, is capable of discolouring the twentieth of its weight of Prussian blue, and is then saturated with the colouring matter; acids disengage a small quantity of blue fecula from it, and it immediately precipitates martial vitriol in the form of perfect Prussian blue.

With regard to the alkali prepared in the usual way, Macquer observes, that it is very far from being intirely saturated with colouring matter; and that, on this account, it first precipitates the solution of martial vitriol of a green colour: in fact, it is the portion of alkali which is saturated that precipitates the iron of a blue colour; but the portion which is not saturated precipitates the iron in the state of ochre, which renders the blue precipitate green by the mixture of this last colour with yellow. In this ingenious theory, the acid poured on the precipitate serves to dissolve the portion which is not in the state of Prussian blue, and consequently renders the colour of this last more intense; the alum added to the solution of vitriol saturates the alkali, which is not charged

charged with colouring matter, and the earth of this salt, deposited with the Prussian blue, renders it less deep. As it is necessary to pour an acid on the precipitate of martial vitriol, in order to render the Prussian blue more lively; this acid may be added to the alkali, before it is used to precipitate the iron, in which case the acid saturating the portion of pure alkali, does not unite to that which is charged with the colouring matter, and therefore leaves it capable of instantly forming a fine Prussian blue. This alkali partly phlogisticated by bullock's blood, may be fully saturated, by digesting it on Prussian blue, till it ceases to deprive it of its colour. Macquer observed, that this alkali saturated with acid, is a good test to the presence of iron in mineral waters; but M. Baumé has remarked, that the liquor itself contains a certain quantity of Prussian blue, which might be productive of error: he therefore proposes to digest it for a sufficient time in a mild heat, with a small quantity of vinegar, that it may deposit all the blue matter it contains.

Such was the admirable series of experiments made by Macquer on the Prussian blue; but this celebrated chemist was himself sensible how much remained to be done, especially with respect to the nature of the colouring substance: he could not be persuaded that it was pure phlogiston,

because on that supposition it was difficult to determine how the iron, overcharged with that principle, became deprived of the property of obeying the magnet, and of solubility in acids, which, according to Stahl, are consequences of the presence of phlogiston in this metal. M. De Morveau is the first, who, in his excellent Dissertation on phlogiston, has attempted to discover the nature of the colouring part of Prussian blue. From two drachms of this compound he obtained by distillation twenty-two grains of a yellow empyreumatic liquor, which caused an effervescence with aerated alkali, strongly reddened blue paper, and of which Geoffroy and Macquer, who likewise distilled Prussian blue, have made no mention.

Mr. Sage, in the year 1772, communicated to the Electoral Academy of Mentz, a Memoir on the phlogisticated alkali, which he calls animal salt. The lixivium of the fixed alkali treated with blood, and digested on the Prussian blue, according to the manner of Macquer, is, as Mr. Sage affirms, a neutral salt, formed by the animal acid and fixed alkali, and affords, by spontaneous evaporation, crystals which are either cubical, octahedral, or quadrangular prisms, terminated by four sided pyramids. This salt decrepitates on charcoal, melts by a violent fire into a semi-transparent mass, soluble in water, and proper to form Prussian blue.

Mr.

Mr. Sage thinks, that the acid which neutralizes the alkali in this salt, is the phosphoric, because when a mixture of alkali and bullock's blood are strongly heated, it melts and emits acrid vapours, accompanied with white and brilliant sparks, which, according to him, are burning phosphorus. This opinion respecting the acid of the Prussian alkali would be proved, if, on the one side, phosphorus were obtained by distillation with charcoal, which likewise would take place with respect to the Prussian blue; and if, on the other side, Prussian blue could be formed by combining the fusible or phosphoric salt with base of vegetable alkali, with a martial solution: but as Mr. Sage has not related any experiments of this nature in his Memoir, his theory cannot be admitted.

The chemists of the Academy of Dijon have adopted part of this last doctrine: in their Elements they consider the phlogisticated lixivium as a solution of a neutral salt; they advise the crystallizing it by evaporation, instead of purifying it by vinegar, as Baumé proposed. This salt is very pure according to them, and causes a detonation when thrown on nitre in fusion: they have said nothing concerning its decompositions, and the nature of its principles; they call it the crystallized Prussian alkali.

Bucquet having precipitated by the marine acid, and filtered a lixivium prepared

for Prussian blue, observed, that this alkali though very clear, and apparently deprived of all the Prussian blue it might contain, nevertheless deposited a blue powder. After having filtered it more than twenty times in the space of two years, to separate the Prussian blue which was deposited after each filtration, he at last found, that the liquor was no longer capable of affording Prussian blue with the solution of martial vitriol. I have still by me a small portion of this lixivium, which has been prepared for near eight years: it is two years since it has deposited any precipitate, but it has deposited a light blueish covering on the sides of the glass in which it is contained, and has itself preserved a similar colour. I have had occasion twice to observe this phenomenon, since I first heard it mentioned by Bucquet, in his Lectures, and I think it is constant. The Duke de Chaulnes shewed Macquer a phlogisticated lixivium, which did not afford Prussian blue when previously mixed with an acid. This chemist supposes that it arises from its having been prepared in metallic vessels. From the observation before recited, Bucquet supposed, 1. That the Prussian blue is entirely contained in the alkali, which serves to precipitate it. 2. That acids alone are sufficient to separate it from the alkali. 3. That when this alkali, at the end of a certain time, has deposited
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all the colouring matter it contains, it is no longer proper to form Prussian blue.

The Journal de Physique for the year 1778, contains observations on Prussian blue, by M. Baunach, apothecary at Metz, which greatly favour the opinion of Bucquet. After having described the process employed in the manufactories in Germany to prepare Prussian blue, M. Baunach affirms, that the lixivium made in these manufactories by the fusion of alkali, and of the hoofs, horns, and skins of oxen, precipitates all the metals, and even calcareous earth, of a blue colour. This alkali dissolves the metals after having precipitated them, and they may be separated of a very beautiful blue colour by the marine acid. The singular facts related in this memoir, such as the distillation of Prussian blue, produced by this lixivium, which affords neither oil nor volatile alkali; the solubility of the blue precipitate (formed by the marine acid, poured on this lixivium) in the nitrous acid; the calcareous earth found in solution in the latter acid, which discoloured the blue; a peculiar and phlogisticated earth which he did not succeed in dissolving.—Do not these circumstances prove, that this blue is not of the same nature with that which is precipitated from the common phlogisticated lixivium, in which Macquer discovered iron that could only come from the blood?

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Since these various inquiries into the nature of Prussian blue, Mr. Scheele has made a number of new researches, which, together with certain observations not yet mentioned, tend greatly to elucidate the nature of this production.

1. The Prussian blue of commerce, distilled with a naked fire, affords a very large quantity of inflammable gas, together with oil, concrete volatile alkali, and a small quantity of acid phlegm. This gas burns blue like the inflammable air of marshes; its smell is empyreumatic; lime-water gives it the property of burning with a red colour, and of detonating with vital air, because it absorbs the cretaceous acid with which it was united. M. De Laffone considered the gas of Prussian blue as a peculiar inflammable gas; Prussian blue, after this analysis, has the form of a blackish powder, obedient to the magnet. Before it takes this colour, it is of an orange colour, as M. De Morveau has observed: the last mentioned chemist even thought, that Prussian blue, after it has been converted to an orange colour by heat, might be useful as a pigment.

2. The volatile alkali heated on Prussian blue, decomposes it, by seizing its colouring matter, and leaves the iron in the state of ochre. Macquer announced this fact in the year 1752. Meyer, who succeeded him, gave

gave the name of tinging liquor to this volatile alkali, saturated with the colouring part of the blue, and advises the use of it in the analysis of mineral waters. I have observed, that when the caustic volatile alkali is distilled from Prussian blue, the fluid which passes over has not the property of giving a blue colour to martial solutions, whence it follows, that the colouring principle is not as volatile as the alkali. When a portion only of this salt is distilled over, the residue is of an olive green; if this be diluted with distilled water and filtered, it is found to be charged with the colouring matter, and affords a very lively Prussian blue, when added to martial vitriol.

3. In the year 1780, I discovered, that lime-water digested by a slight heat on Prussian blue, dissolves the colouring matter; the combination is quickly effected, the lime-water being coloured, and the Prussian blue assuming a rusty appearance; the lime-water after filtration, is of a beautiful clear yellow colour, no longer capable of converting syrup of violets to a green; no longer of an alkaline taste, nor precipitable by the cretaceous acid; it does not unite with other acids, and in a word, it is neutralized by the Prussian colouring matter, and affords, when poured on the solution of martial vitriol, a very fine blue, which does not need an acid to enliven its colour. Mr. Scheele

speaks of this Prussian lime-water, doubtless without being previously acquainted with my experiments on the subject, though they were inserted in my Elements of Chemistry, printed in the year 1781. He, as well as myself, considers this combination as the best of those which have been proposed as tests of the presence of iron, because it does not contain Prussian blue ready formed.

4. Caustic fixed alkalies discolour the Prussian blue immediately in the cold. I have observed that a considerable heat is produced in these experiments; that the alkalies in a state of purity discolour a much greater quantity of Prussian blue than those which are saturated with cretaceous acid, and that they precipitate a large quantity of the blue with martial solutions.

5. I found that magnesia has likewise the property of discolouring Prussian blue, though much more weakly than lime-water.

6. Prussian blue thrown in powder on melted nitre, produces some sparkles, which denote that it contains a combustible matter.

7. Prussian blue prepared without alum, becomes strongly attracted by the magnet by a slight calcination; but the Prussian blue of commerce never acquires that property by the action of fire.

8. Prussian

8. Prussian blue discoloured by alkaline matters, and in the state of ochre of iron, re-assumes a blue colour when an acid is added: this circumstance seems to depend on the whole of the colouring matter not being taken away by the first action of the alkalies, and that a portion is defended by the external stratum of ferruginous calx.

All these facts shew, that the colouring part of Prussian blue is a peculiar acid, which saturates alkalis, and forms neutral salts; this opinion is adopted by many chemists, and in particular by Mr. Scheele, whose researches on this matter only remain to be related. This celebrated chemist has proved by his experiments, 1. That a lixivium of blood, or phlogisticated alkali, is decomposed by the cretaceous acid of the atmosphere, and that all the other acids separate the colouring matter. 2. That this colouring matter is fixed and retained in the lixivium, by a small quantity of iron, or of pure vitriol of iron. 3. That when it is disengaged by acids in distillation, it fills the receiver with a vapour, which precipitates the solutions of iron of a blue colour. 4. That Prussian blue distilled without addition, as well as the lixivium of blood, affords, together with the colouring matter, foreign products, which alter it, such as sulphur; and that the colouring matter cannot be had pure by this process. 5. That

5. That Prussian alkalies distilled with the vitriolic acid, precipitate a large quantity of Prussian blue, and afford a liquor charged with the colouring matter. The portion of blue precipitated in this operation depends on the iron dissolved in these triple salts, or combinations of alkalies, colouring matter, and iron. 6. That the calx of mercury or red precipitate, seizes the colouring matter of Prussian blue, by ebullition, in double their weight of water; and that if this mercurial Prussian lixivium be distilled with the addition of iron and vitriolic acid, the iron reduces the mercury, and the acid disengages the colouring matter; this last becoming dissolved in the water of the receiver, in proportion as it is disengaged, and retaining a portion of vitriolic acid. To separate them, Mr. Scheele mixes a small quantity of chalk with the liquor, and distills by a gentle heat: the colouring matter passes over in a state of great purity, and as it is disengaged in the form of an elastic fluid, as M. Mongez also observed, it may be received in water by the assistance of tubes, or the pneumatological apparatus, which has already been often mentioned.

After these researches concerning the affinities of the colouring Prussian matter, its adherence with alkalies, and the method of obtaining it perfectly pure, Mr. Scheele, in a second Memoir, inquires into the nature of
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of this substance, and its combinations with alkalies and metallic calces; and though his experiments are numerous, and very accurate, he does not prove that the colouring matter is a peculiar acid; on the contrary he proves, that it contains inflammable gas, volatile alkali, and a carbonaceous principle. He however has observed, that it possesses the property of coagulating soap, and precipitating hepars; and he calls it the colouring acid, in a letter to Mr. Crell. M. De Morveau calls this substance by the name of Prussian acid, and distinguishes its saline combinations, according to his nomenclature, by the names of Prussites; as for example, Prussites of pot-ash, of soda, &c. In a note by the translator of Mr. Scheele, it is asserted, that this acid is decomposed by the acid of nitre, and a process of Mr. Westrumb, to obtain the Prussian alkali in a state of great purity, is given. It consists in saturating caustic vegetable alkali with the colouring matter, digesting it on white lead, to deprive it of the hepatic gas it may contain, mixing it with distilled vinegar, and exposing it to the sun, as Messrs. Scopoli and Father Bercia advised to precipitate the iron; after which two parts of rectified spirit of wine are added. The Prussian alkali is then deposited in lamellated and brilliant flocks, which being washed in fresh spirit of wine, is afterwards dried, and dissolved in distilled water.

water. Mr. Scheele, three months after Mr. Westrumb, forwarded to Mr. Crell an analogous process for obtaining in proof liquor, which might be depended on as a test of the presence of iron.

Martial vitriol decomposes nitre very readily. This decomposition is partly due to the vitriolic acid, which uniting with the alkali of nitre, disengages the acid of that salt; but it is likewise in a great measure occasioned by the re-action of the iron on the latter acid. If martial vitriol slightly dried be taken for this experiment, a considerable quantity of nitrous acid, very red and fuming, is obtained; the residue, by lixiviation, affords vitriolated tartar and fixed alkaline salt; the mild earth of vitriol, remains on the filter: but if strongly calcined vitriol be made use of, together with nitre which has suffered fusion, the product obtained is very inconsiderable. This product consists of two liquors; the one of a dark, and almost black colour, floats on the surface of the other, which is red and ponderous; for which reason M. Baumé considered this liquor as a kind of oil: there afterwards passes into the neck of the retort, a white saline mass, which attracts the humidity of the air, and is soluble with heat, and great rapidity in water, emitting a strong smell of spirit of nitre, and very thick red vapours: this solution saturated with fixed vegetable

vegetable alkali, affords vitriolated tartar; the white mass therefore is merely oil of vitriol rendered concrete by a portion of nitrous gas.

The heavier liquor in the receiver does not, on examination, appear to differ from Glauber's spirit of nitre; but the lighter liquid which floats above it, being mixed with oil of vitriol, produces a strong effervescence, and sometimes a dangerous explosion; almost all the nitrous acid is dissipated, and the oil of vitriol takes a concrete and crystalline form. Bucquet, who communicated this discovery to the Academy, had before observed, that the concrete oil of vitriol obtained in this distillation, emits red nitrous vapours when dissolved in water; he supposed that this acid owes its solid form to the presence of nitrous gas, and in order to ascertain the truth of this conjecture, he attempted to mix the brown blackish nitrous acid which floats over the red liquor with very concentrated oil of vitriol; but at the very instant of the mixture of these two fluids, a commotion was excited, of so strong a kind, that the spirit of nitre, poured on the vitriolic acid, was thrown with considerable noise to a great distance; the person who made the mixture was covered with the acid, and a large quantity of red and inflamed pimples instantly rose on his face, which suppurated like those of
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the small-pox; the oil of vitriol soon became concrete, and absolutely similar to that which is obtained in the distillation we have described. From this fact it appears, that the acid may become concrete as well by imbibing nitrous, as sulphureous gas.

The residue of the distillation of nitre with martial vitriol calcined to redness, is merely a coria of iron, from which a very small quantity of vitriolated tartar may be obtained by washing.

The solution of martial vitriol is not altered by inflammable gas, because the base of this elastic fluid has less affinity with the oxygenous principle than iron; as we have seen in the history of the decomposition of water. M. Monnet has however observed, that hepatic gas communicates to vitriolic mother water the property of affording crystals.

Liver of sulphur precipitates martial vitriol of a blackish colour; the precipitate is a kind of martial pyrites.

The nitrous acid is very rapidly decomposed by iron, which disengages a large quantity of nitrous gas, especially if the acid made use of be concentrated, and the iron in a state of division: this metal is quickly calcined by the oxygenous principle it seizes from the nitrous acid; the solution is of a brown red, and deposits calx of iron at the end

end of a certain time, especially if in contact with the air. On the addition of more iron the acid dissolves it, as Stahl has observed, and the calx of iron before held in solution is precipitated; nevertheless, when a weak nitrous acid is used, and iron in pieces, a more permanent solution may be obtained, in which the metal adheres more strongly to the acid. This last combination is greenish, and sometimes of a bright red; both solutions become turbid by evaporation, and deposit martial ochre of a reddish brown; but if the latter be strongly concentrated, instead of affording crystals, it takes the form of a reddish jelly, which is only in part soluble in water, the greatest part precipitating. If the nitre of iron be kept heated, red vapours, in large quantities, are disengaged, the magma becomes dry, and affords a calx of a brick dust red colour; this magma, by distillation in a retort, affords a small quantity of fuming nitrous acid, much nitrous gas, and atmospheric mephitic. Vital air cannot be obtained, because the iron retains all the oxygenous principle of the acid; the calx which remains after the distillation of nitre of iron, is of a lively red, and may afford a good colour for painters, &c. The nitrous solution of iron, however concentrated, did not appear to afford a precipitate by the addition of distilled water; alkalies decompose it with different phenomena, according to their nature;

nature; caustic vegetable alkali precipitates it of a light brown colour; the mixture passes very quickly to a blackish brown, and much deeper than the colour of the first solution. This phenomenon arises from the portion of the precipitate dissolved by the alkali, though the quantity be very small; cretaceous vegetable alkali separates a yellowish calx, which quickly becomes of a beautiful orange red; if the mixture be agitated, an effervescence takes place, the precipitate is re-dissolved in much greater abundance than that produced by the caustic alkali. M. Monnet took notice of this phenomenon, and has with justice attributed it to the gas which is disengaged. The solution of iron by fixed alkali, is called the martial alkaline tincture of Stahl, and of a very beautiful red. M. Baumé recommends a nitrous solution of iron, which is not highly charged, to be used for the preparation of this tincture: Stahl, on the contrary, advises a very saturated solution. M. Monnet has observed, that a yellow solution affords a very large quantity of precipitate, which is not resolvable by the alkali, and does not give the colour expected in the martial tincture; while a red solution immediately produces it with the same alkali. The martial alkaline tincture of Stahl loses its colour at the end of a certain time, and deposits the calx of iron it contains; it may be

be decomposed by the addition of an acid; the nitrous acid separates a calx of a brick-dust colour, which is soluble in acids, and is called Stahl's aperitive saffron of Mars: pure or caustic volatile alkali, precipitates the nitrous solution of iron of a deep, and almost black green; ammoniacal chalk re-dissolves the iron which it separates from the acid, and assumes a more lively red colour than the tincture of Stahl. This solution of iron by the cretaceous volatile alkali, may be used to great advantage in cases wherein a powerful tonic and solvent medicine is required.

The nitrous solution of iron highly saturated, and red, afforded me but a very small quantity of Prussian blue, by the addition of an alkali saturated with the colouring matter. I obtained only a blackish precipitate, which was re-dissolved by the marine acid; the liquor had then a green colour.

M. Marett, secretary to the Academy of Dijon, has communicated to the Royal Society of Medicine, a process for making martial *Æthiops* very expeditiously; it consists in precipitating the nitrous solution of iron by the volatile caustic alkali, and quickly washing and drying the precipitate. M. D'Arcett, who was appointed by the last mentioned society, to examine the process of M. Marett, did not constantly obtain the same result. In my Memoirs on martial

precipitate, I have determined the cases in which the experiment of M. Marett succeeds, and those in which it fails. To obtain this *Æthiops* it is necessary, 1. That the solution of iron be recently made in the cold, with a weak nitrous acid, and iron not much divided. 2. That the volatile alkali be recently prepared exceedingly caustic, and especially that it be deprived, by standing, of the small portion of calcareous earth, and blackish combustible matter which it usually carries up from the sal-ammoniac and lime. 3. That the precipitate be immediately separated from the liquor, and quickly dried in closed vessels. Notwithstanding all these precautions, the precipitate is not always intensely black, but inclines towards a brown, and rises up in the form of scales, whose inferior surface is blackish; which shews that it is the contact of air which slightly rusts the superior surface. I have obtained a more beautiful *Æthiops*, and with greater certainty, by precipitating the marine and the acetous solution of iron by caustic fixed and volatile alkalies, and quickly drying the washed precipitates in close vessels; but I think, notwithstanding, that these *Æthiops*, however pure they may be supposed, always retain a small part of their precipitants, and their original solvents, as M. Bayen has observed concerning the precipitates of mercury; and that they

they cannot be employed in medicine with the same certainty as those heretofore described. M. D'Arcett, in his report to the Royal Society of Medicine, concerning the process of M. Marett, has communicated a process of M. Croharé, for making *Æthiops martial*. This apothecary, who is well known by the many chemical experiments he has skilfully made, prepares this medicine by boiling water, acidulated by a small quantity of nitrous acid, on filings of iron; the metal becomes immediately very minutely divided, and affords much *Æthiops*. But I think that the process of M. Joffe is preferable to every one of these, on account of its facility in practice, and the confidence with which its product may be used.

As iron is often used for obtaining nitrous gas, it is of consequence to take notice, in this place, that the gas is never the same, but differs greatly, according to the various circumstances of the solution; the nature of the acid more or less charged with mephitic, or the oxigenous principle; the state of the iron, more or less greedy of that principle; the various temperatures, &c. In general gas, prepared by this process, always contains a considerable quantity of mephitic; because the iron is a body which absorbs the oxigenous principle very strongly, and seizes different quantities according to its nature and its metallic state. The ef-

fects of the gas, disengaged by means of this metal, are therefore uncertain when applied to eudiometrical researches. This truth, which is applicable to all bodies that separate the nitrous gas from the acid of nitre, shews how little the trials of air by eudiometers with nitrous gas are to be depended on. Experiments of this nature made with liver of sulphur are much preferable.

The muriatic acid, diluted with water, dissolves iron with rapidity, and disengages a large quantity of inflammable air, produced by the decomposition of the water, as happens when this metal is dissolved in spirit of vitriol. It was formerly thought that the inflammable gas produced by the action of iron on the muriatic acid was different from that which is disengaged by the vitriolic acid: it was thought that this elastic fluid was one of the principles of the muriatic acid; but the discovery of the decomposition of water by iron, renders it more probable that this acid, whose nature is yet unknown, is not the cause of the production of inflammable gas, but that it arises from the water. The solution of iron by the muriatic acid is attended with much heat, which continues with the same force till the acid is saturated; a proportion of the iron is precipitated in a true *Æthiops*, as happens in all the other solutions after filtration:

tion: this solution is of a green colour, inclining to yellow, and is much more permanent than the two preceding solutions; when preserved in a well stopped phial, it does not deposit iron. I have kept a solution of this nature for eight years, which has deposited only a very small quantity of powder, of a pale yellow: but if, on the contrary, it be exposed to the air, almost all the iron it contains is precipitated in a few weeks, and this precipitate is of a lighter colour in proportion as the access of the air is the easier. It is now proved that this precipitation, which takes place equally in all the other solutions of iron, is produced by the base of vital air absorbed by the metal, which becomes calcined more and more, as I suspected in the year 1777. See my *Memoires de Chimie*.

Stahl affirmed, that in the combination of iron with the muriatic acid, the acid assumed the characters of that of nitre; but this fact has not been observed by any other chemist. It seems that Stahl depended only on the yellow colour of this solution, and the smell it emits; a smell which, in fact, differs in some respects from that of spirit of salt, and approaches to that of the aerated muriatic acid.

The solution of iron by the muriatic acid does not crystallize regularly by evaporation. M. Monnet has observed, that if

it be suffered to cool when it has acquired the consistence of syrup, it forms a kind of magma, in which may be seen needle-form flat crystals, which are very deliquescent. This magma melts by a very gentle heat, and seems to deserve the name of butter of iron; a greater heat decomposes it, though less readily than martial nitre, and it assumes the colour of rust when it is dry; the muriatic acid is disengaged from it, and may be obtained by distillation; it carries up with it a small quantity of calx of iron, according to the observation of Brandt. The Duke D'Ayen, in one of the four excellent memoirs he communicated to the academy, respecting the combinations of acids with metals, has very minutely examined what passes in this decomposition of the muriate of iron. The operation afforded very singular products: a mild heat disengaged a phlegm slightly acid; the muriatic acid then became concentrated, and its gas, which is much more volatile than water, was partly fixed by the iron; a much stronger heat raised a portion of this acid with a small quantity of iron, and crystals were formed in the receiver, which were not deliquescent; very transparent crystals in the form of blades of razors, which decomposed the light in the manner of the best prisms, and exhibited very beautiful tinges of red, yellow, green, and blue, were at the same

same time sublimed to the upper part of the retort; at the bottom there remained a styp-tic and deliquescent salt, of a brilliant colour, and foliated texture, which perfectly resembled that kind of talc, in large plates, which is improperly called Muscovy glass. This last salt, exposed to a violent heat in a stone-ware retort, was decomposed, and afforded a sublimation still more astonishing than the former products; it was an opaque matter truly metallic, which, when examined by the microscope, exhibited regular crystals, or sections of hexagonal prisms, which the Duke D'Ayen compares to the pieces inlaid in floors: these crystals were as brilliant as the most highly polished steel, and were strongly attracted by the loadstone. They consisted therefore of iron reduced to the metallic state, and sublimed.*

Art appears here to imitate nature, which sublimes iron by volcanic fires, in the form of brilliant and well polished laminæ, resembling steel; such at least appears to be the origin of the specular iron ore, and of that of Volvic, which, according to the valuable

* I have in my possession a black ore of iron, which exhibits very brilliant small laminæ, of half a line in breadth, whose form nearly approaches to that of the crystals obtained by the Duke D'Ayen; they are small very thin scales, of a very brilliant iron grey colour, placed slopewise, so as to intersect each other in every direction, and are dispersed on a reddish opaque quartz, or a kind of coarse jasper: this beautiful specimen came from Lorrain.

observations of M. De L'Arbre, physician at Riom, is always found in the clefts of lavas.

From these details we may perceive how rich the science of chemistry is in curious phenomena, and what a fund of discovery is held forth to such as perform experiments with all the accuracy of the Duke D'Ayen. We must not forget to observe, that this reduction of iron favours the doctrine of gases, and that we may perhaps obtain similar results from many other metallic solutions treated in the same way.

The muriatic solution of iron, like all other martial solutions, is decomposed by lime and alkalies; but the precipitates are less altered, and may be easily reduced, especially such as are produced by the addition of caustic alkalies. I have before observed, that this combination affords the purest *Æthiops* by precipitation; the liver of sulphur, hepatic gas, and astringents, decompose it like the two others. Lastly, Prussian alkalies and Prussian salts precipitate a beautiful blue powder.

Water charged with the cretaceous acid, easily dissolves iron: to form this combination, nothing more need be done, than to add iron filings to the acid spirit of chalk, and leave the mixture in digestion for some hours; this fluid, when filtered, has a penetrating and rather styptic taste. Messrs, Lane and Rouell have taken notice of this
property

property in the cretaceous acid. Bergman, who calls this combination aerated iron, affirms, that when exposed to the air, it becomes covered with a pellicle of rainbow colours; that it is decomposed by the pure alkalies, but that these salts, when aerated or cretaceous, do not produce the same effect. This solution converts the syrup of violets to green, and affords very brilliant Prussian blue with the calcareous Prussites; it affords a precipitate of martial ochre when left exposed to the air, or when heated: this combination may be called martial chalk. Iron has a strong tendency to unite with the cretaceous acid, and nature very frequently presents it in this state. The muddy iron ores and spathose iron, appear to be entirely formed by this combination; ferruginous mineral waters often contain iron in the state of martial chalk. This salt separated from the water and dried, is scarcely soluble in that fluid, but it dissolves in a large proportion in the cretaceous acid spirit; from which it is precipitated, in proportion as the acid is volatilized. The action of the sedative and fluor acids on iron is not known.

This metal decomposes vitriolic salts very readily, and in particular the vitriol of potash, and the vitriol of soda. I have treated these salts with iron in a crucible, and have found them to be in the hepatic state. The lixivium of this kind of hepar, is of a very deep

deep green ; a few drops of acid caused the colour to disappear very quickly. The greatest part of the iron calcined by the oxygenous principle of the vitriolic acid, remains without dissolving in the lixivium, and acids disengage a large quantity of hepatic gas from this calx.

Iron causes nitre to detonate. When equal parts of steel filings, and very dry nitre, are thrown into a well ignited crucible, a very rapid commotion is excited, after a little time, and a great number of brilliant sparkles fly out of the crucible. When the detonation is ended, the crucible contains a reddish calx of iron, of which a small portion is combined with the alkali ; water dissolves the alkali, and the martial calx remains on the filter. This is called Zwelfer's saffron of Mars, and is of a yellowish red, scarcely soluble in acids ; the alkali separated by the lixiviation, is caustic, according to most chemists, who think that metallic calces act like pure lime on this salt, charged with the cretaceous acid.*

* It must be observed, that since the promulgation of the theory of Dr. Black, respecting the causticity of lime and alkalies, the necessary experiments have not been made, to ascertain this parity of action between lime and metallic calces ; nothing can therefore be said respecting this, till such experiments have been made. Note of the Author.

Iron

Iron decomposes sal-ammoniac, or ammoniacal muriate, very readily: two drachms of steel filings triturated with one drachm of sal-ammoniac, disengage alkaline gas. Bucquet, who distilled this mixture in the pneumato-chemical apparatus, with mercury, obtained fifty-four cubic inches of an aeriform fluid, half of which was alkaline gas, and the other half inflammable gas. Four ounces of the same filings, and two ounces of sal-ammoniac, distilled in the retort with the common receiver, afforded about two drachms of alkaline spirit, containing a small quantity of iron, which was soon after deposited in the form of ochre; the residue of these operations was martial muriate. The decomposition of sal-ammoniac by iron, is a consequence of the facility with which this metal unites with the muriatic acid, which is proved by the disengagement of inflammable gas observed in this experiment. A salt is prepared for medical uses, with sal-ammoniac and iron, which is called martial flowers of sal-ammoniac, or ens martis. One pound of sal-ammoniac in powder, and one ounce of iron filings are mixed together. The mixture is exposed in an earthen vessel, covered with a vessel of the same kind, to a heat capable of igniting the lower part of the apparatus: in five or six hours a yellow matter is sublimed, which is preserved in a bottle: this

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is the martial flowers, and consists mostly of sal-ammoniac sublimed, with a small quantity of calx of iron. As this metal decomposes sal-ammoniac very readily, it must only be employed in small quantities, in order that the greatest part of the salt may sublime in its proper state. The portion of martial calx which is volatilized, colours the sal-ammoniac sublimed at the same time.

Calx of iron decomposes this salt more readily than the metal itself, since it disengages the volatile alkali in the cold. The alkali obtained by distillation is very fluid and caustic. I have obtained volatile alkali, which made a slight effervescence with acids, by distilling sal-ammoniac with half its weight of aperitive saffron of Mars, or martial chalk; in this experiment the cretaceous acid disengaged from the iron, unites with the volatile alkali, and rendered it effervescent.

Iron is altered by inflammable gas, but this change, which is very sensible with respect to colour, has not been examined in other respects. The calx of iron is not decomposed by this gas, which has less affinity with the oxygenous principle than the metal has, as is proved by the decomposition of water by means of fire.

Sulphur combines rapidly with iron: a mixture of iron filings and sulphur in powder, moistened with a small quantity of water, becomes hot in a few hours, at which time
it

it swells up, its parts adhere together, it absorbs the water, breaks with a perceptible noise or crackling, and emits aqueous vapours, attended with a very manifest hepatic odour, slightly resembling that of inflammable gas. If the mixture be made in a large quantity, it takes fire in twenty-four or thirty hours, as soon as the aqueous vapours have ceased. Towards the end of the action of these substances on each other, the heat becomes greater and greater, and is quickly succeeded by the inflammation; the smell is then much stronger, and appears to arise from the inflammable gas produced by the re-action of the sulphur and the iron on the water. This smell is a mixture of that of liver of sulphur and of pure inflammable air, and is doubtless owing to the large quantity of this gas which is disengaged, that the inflammation is due; for the flame is much more lively than that of sulphur, and it rises to a foot in height, according to the report of M. Baumé, who observed this phenomenon with a mixture of an hundred pounds of filings, and as much sulphur in powder, did not last longer than two or three minutes; but the mixture remained red hot for forty hours. M. Baumé explains this inflammation, by the disengagement of the phlogiston of the sulphur, in the form of fire set at liberty. Lemery the elder gave the name of artificial volcano to

to this experiment, and imagined that the fires which burn in the interior part of our globe, and by raising the surface produce earthquakes and volcanoes, were owing to a similar combustion of pyrites in large masses moistened. These terrible effects may be imitated, according to the same chemist, by burying in the earth a mixture of sulphur in powder, and filings of iron reduced into a paste, with water, and covering it up with earth strongly rammed down. The experiment however did not succeed with Bucquet, who repeated it with great exactness; and the reason may be easily deduced, from the experiments of Priestley. This philosopher observed, that a mixture of iron and sulphur, when moistened, absorbed a certain quantity of air, which doubtless is necessary for this inflammation; and the latter fact agrees very well with the theory of M. Lavoisier, respecting the decomposition of water. In fact it appears, the iron which is greatly divided, re-acts on the fluid, seizes its oxygenous principle by which it is calcined, and suffers the inflammable gas to be disengaged, which takes the elastic form, by reason of the heat separated from the water: the gas likewise dissolves a portion of the sulphur, and forms hepatic gas.

There is a great analogy between this combination of iron and sulphur, by the humid way, and the efflorescence of pyrites, which

which afford inflammable and hepatic gases, when they are moistened with water.

Sulphur combines very readily with iron by fusion, and produces a pyritous mass, disposed in needles. As the sulphur in this case greatly increases the fusibility of iron, that metal may be instantly fused by the assistance of the combustible body. For this purpose, a small bar of iron, heated to whiteness, may be applied to a roll of sulphur, and the melted matter which drops, may be received in a vessel of water; it is found to consist of blackish brittle globules, similar to pyrites, and like them formed of small slender pyramids, converging to a centre.

Iron combined with arsenic, affords a brittle alloy, very little known.

With cobalt it constitutes a mixed metal, close-grained, hard, and difficult to break.

It does not appear capable of uniting with bismuth.

Combined with regulus of antimony, it forms a hard alloy, with small facets, which scarcely yields to the hammer. Iron has a stronger affinity with sulphur than with this regulus, and consequently is capable of decomposing antimony. To effect this, five ounces of the points of horse-shoe nails are heated red hot in a crucible; a pound of pulverized antimony is then thrown in, and a strong heat suddenly given to melt the mixture: when it is well fused, an ounce of nitre in
powder

powder is added, to assist the fusion, and facilitate the separation of the scoriæ from the regulus. The mixture being suffered to cool, a regulus of antimony is found in the crucible, which does not contain iron; but if one part of iron be used with two of antimony, the regulus will be martial. The scoriæ, which are found above this last regulus, prepared with nitre and tartar, have a yellowish colour, similar to that of amber, produced by the iron they contain, whence Stahl called them succinated scoriæ. He directs them to be reduced into powder, and boiled in water, which takes up the most subtle part of the powder; after which the fluid must be decanted off, filtered, and the powder on the filter detonated three times with nitre: this being washed and dried, is Stahl's aperitive and antimoniated saffron of Mars.

It is still uncertain whether zink be capable of uniting with iron. Malouin, in his memoir on zink, published among those of the Academy for the year 1742, has shewn, that this semi-metal may be applied, like tin, to the surface of iron, for the purpose of defending it from the contact of air, a circumstance which shews, that these two metallic matters are capable of combining.

It seems that nickel is capable of being very intimately united with iron, since these
two

two metallic substances can never be perfectly separated, as Bergman has demonstrated.

Mercury does not contract any union with iron in its metallic state; it has in vain been attempted to unite these two metals immediately, but the combination is successfully made by presenting them to each other in the state of calx. Navier has observed, that a whitish snowy precipitate is obtained, by mixing a solution of iron and of mercury by the vitriolic acid, and evaporating the mixture; in this operation small flat crystals, similar to those of sedative salt, are formed. Navier affirms, that these crystals are a combination of iron and of mercury.

Lead is not capable of uniting with iron.

Iron and tin appear susceptible of union by fusion. The preparation of white iron, or, as it is commonly called, tin, which consists of iron plates covered with a thin stratum of tin, shews that this combination takes place. In order to tin iron, it is necessary that the surface of the metal should be very clear and bright: for that purpose it is corroded by an acid, or sometimes filed or scraped, or covered with a solution of sal-ammoniac; it is afterwards plunged vertically into a vessel of melted tin; moved backwards and forwards, to increase the contact, and when sufficient-

ly tinned, it is taken out and rubbed with saw-duft, or bran, to clear off the fat or pitch with which the melted tin was covered, and which adheres to the surface of the tinned iron. If iron reduced into very thin laminæ, be tinned, the tin will not only apply to the surface, but will penetrate into its internal parts, and the combination will be perfect throughout, so that when it is cut, the same white colour will be observed in the middle as at its surface, a circumstance which shews, that well made tin-plate is a true chemical combination; it is besides more malleable than iron, and is wrought into vessels of such forms, as it would be impossible to give to pure iron by the hammer.

The uses of iron are so great and extensive, and besides so well known, that it would be useless to attempt to enumerate them: it is only necessary to observe, that no art can be carried on without it, and that it is the soul of all the arts, as Macquer observes. The different modifications it is susceptible of, render it very proper for the multiplicity of purposes to which it is applied. Cast iron serves to form utensils of various degrees of solidity as may be required. The hardness and tenacity of the several kinds of forged iron are no less applicable to other uses. The same observation is applicable to steel: the fineness of the grain,

grain, and excellence of the temper, constitute a great number of species, peculiarly adapted to an almost infinite number of arts. The calces of iron serve to give a red or brown colour to porcelain, enamel, pottery, &c. they are likewise used in the preparation of artificial precious stones, and combined with oil for painters. Iron is the basis of an important medicine, which is frequently applied with the greatest success. It is the only metal which is not noxious, and whose effects are not to be feared; it has, even as we have seen, such an analogy with organic matters, that it seems to form part of them, and often owes its production to the processes of life or vegetation. The effects of iron on the animal economy are numerous; it stimulates the membranes of the viscera, and appears to act more especially on those of the muscles, which it braces; it fortifies the nerves, and gives a remarkable degree of force and vigour to the animal system; it excites many secretions, especially the urinary and menstrual evacuations; it increases the contractions of the heart, and consequently renders the pulse stronger and quicker. Its action is not less effectual on the fluids; it passes quickly through the first passages, and combines with the blood, to which it gives density, consistence, and colour, rendering it more concrescible, communicating at the

same time such a degree of activity, as enables it to pass easily into the smallest vessels, which it stimulates at the same time, and communicates force and life through every part. The capital experiments of M. Menghini, published in the Memoirs of the Institution of Boulogne, have proved, that the blood of persons, who take martial medicines, is higher coloured, and contains a larger quantity of iron than it would naturally contain. Lorry, who exercises the art of medicine with that accuracy of observation which characterizes the true philosopher and physician, observed, that the urine of a patient to whom he had given iron, in a very divided state, became manifestly coloured with nut-gall. This medicine is therefore tonic, fortifying, stomachic, diuretic, alterative, incisive, and unites in its action the properties of a great number of other medicines. Like astringents, it increases the motion of the parts, and has the advantage of being more constant and durable in its effects than many other remedies which possess the same virtue, because it combines with the organs themselves, by means of the fluids which serve for their nutrition. It seems therefore, that in every case wherein the fibres of the viscera, of the muscles, or even of the nerves, have only a very feeble action, in languors of the stomach, and sluggishness of the intestines,

tines, and in weakneſſes produced by theſe cauſes; in fine, in all the caſes wherein the fluids are not ſufficiently conſiſtent, or too much diluted, as in palsies and propenſities to the dropſy, &c. martial medicines may be adminiſtered with ſucceſs. It is uſed under many different forms, ſuch as the levigated filings, martial ethiops, aſtringent and aperitive ſaffron of Mars, martial alkaline tincture of Stahl, the martial flowers of ſal-ammoniac, &c. to theſe we may perhaps add, iron precipitated by an acid, and re-diſſolved by volatile alkali; the Pruſſian blue propoſed by the chemiſts of the Academy of Dijon, &c. Martial vitriol is externally uſed in hemorrhages, &c.

Iron poſſeſſing the magnetic property, or the artificial magnet, is ſaid to produce very ſingular effects on the animal economy: when applied to the ſkin, it mitigates pain, diminiſhes convulſions, excites redneſs, ſweat, and often a ſmall eruption; it ſeems likewiſe to render epileptic fits leſs frequent; it is affirmed, that by being left twelve hours in water, it communicates a purgative property to that fluid. Though all theſe effects require to be confirmed by repeated experiments, yet it cannot be doubted, but that the magnet has very ſenſible virtues. M. Thouret, phyſician of the faculty at Paris, and of the Royal Society of Medicine, has communicated in the firſt volume of the

History of the last mentioned Society, a valuable observation relative to this subject. A patient at Rouen removed a fixed pain into different branches of the seventh pair of nerves which are spread on the face, by applying a loadstone to the different parts of this region; the skin seemed to rise to the magnet. There is no doubt but new observations will offer themselves in support of these discoveries, and enlighten a part of natural philosophy, which certain persons have endeavoured to render more interesting, by affecting concealment.*

C H A P. XVIII.

Concerning Copper.

COPPER is an imperfect metal, of a red brilliant colour, to which the alchemists have given the name of Venus, on account of the facility with which it unites to, and becomes changed by, a great number of bodies. It has a disagreeable smell, which is more sensible when it is rubbed or heated; its taste is styptic and nauseous, though less perceptible than that of iron; it is hard,

* The surprising effects of a certain piece of mummery, which its practioners called animal magnetism, and which engrossed much of the attention of the inhabitants of Paris a few years ago, has been proved by the commissioners of the Royal Academy, to depend merely on the imagination of the patient. See *L'Histoire de l'Academie Royale des Sciences* 1784, pag. 11. Note of the Translator.

elastic,

elastic, and sonorous, very ductile, and capable of being reduced into exceedingly thin leaves, or fine wire; by immersion in water it loses between one eighth and one ninth of its weight; its tenacity is such, that a copper wire of the tenth of an inch in diameter, can sustain a weight of $299\frac{1}{4}$ pounds before it breaks; its fracture appears composed of small grains; it is susceptible of a regular form; the Abbé Mongez describes its crystals as quadrangular pyramids, sometimes solid, and sometimes composed of other similar small pyramids, laterally adhering.

Copper is found in the earth in various states; its ores are very numerous, but may all be referred to the following.

1. Native copper having the red colour, the malleability, and all the other properties of this metal. It is distinguished into two kinds, copper of the first formation, and copper of the second formation, or of cementation. The copper of the first formation is dispersed in laminæ, or fibres, in a gangue almost always quartzose; some of its crystals resemble a kind of vegetation, other specimens are in masses or grains. Copper of cementation is commonly in grains, or superficial laminæ, on stones or on iron: this last appears to have been deposited in waters, containing vitriol of copper which has been precipitated by iron. Native copper is found in many parts of Europe;

Europe; at St. Bell, in Lyons; at Norberg, in Sweden; at Newfol, in Hungary; and in several parts of America.*

2 Copper mineralized by the cretaceous acid: there are several varieties of this ore.

A. Red copper, or hepatic ore of copper. This ore is known by its red dusky colour, similar to that of the scales which are detached by the hammer from red hot copper. M. Monnet considers this ore as native calx of copper; it is usually mixed with native copper and mountain green; it is rare, and sometimes crystallized in octahedrons, or filky fibres, called flowers of copper.

B. Earthy copper, mountain green, or green chrysocolla. This ore is a true ochre of copper, of a more or less deep green, not heavy, and unequally distributed on its gangue: it appears to be combined with the cretaceous acid, according to the analysis made by the Abbé Fontana of the malachite. It is sometimes very pure, and is distinguishable into three states.

Simple mountain green, earthy or impure, called likewise green chrysocolla.

Crystallized mountain green, or filky copper ore of China; this ore, which is common in the Hartz, is likewise found in China; it is very pure, and crystallized in long filky bundles, of considerable solidity.

* And in various places in England, Scotland, and Wales. T.
Mountain

Mountain green in stalactites, or malachite; this substance is found frequently in Siberia, is composed of beds which represent nipples of various magnitudes; some specimens are composed of needles, converging towards a common centre; the different layers have not the same shades of green. The grain of malachite is sufficiently hard to receive a good polish, and is therefore worked into different toys; but as it is frequently porous, and full of unequal cavities, the solid pieces of a certain size are reckoned valuable.

To these three states we may add a beautiful green sand, brought by M. Dombey from Peru, which appears to be a calx of this metal, mixed with sand, and containing a small quantity of muriatic acid, as I found by analysing it.

C. Mountain blue, or blue chrysocolla. It is a calx of copper, of a deep blue colour, sometimes regularly formed in rhomboidal prismatic crystals of a fine blue; it is then called azure of copper. At other times it has the form of small grains, disposed in a cavity of different gangues, especially quartz; it usually constitutes superficial layers in the cavities of the grey and yellow copper ores. All these calces of copper appear to have been precipitated from vitriolic solutions of copper, by the intermedium of calcareous earths through which the waters have transuded. Mr. Sage considers these blue copper ores as combinations

tions of copper with the volatile alkali, from which he affirms they differ only in their less degree of solubility; he likewise thinks that the malachites is produced from this blue, which he calls transparent azure copper ore; but the greater number of mineralogists have not adopted this opinion. M. De Morveau thinks that blue calx of copper does not differ from the green calx, but in the circumstance of its being less calcined.

The blue calx of copper colours certain stones, more especially turquois stone, in which Reaumur found copper, and the lapis armenius, whose base is calcareous earth, or gypsum. Mr. Kirwan reckons these blue stones as a species of copper ore. The Turquois stone is formed of the bones of animals, coloured by copper; those of Prussia are not attacked by the nitrous acid, according to Reaumur; but those of Languedoc are completely soluble in that menstruum.

3. Copper mineralized by the muriatic acid, and united to clay. Mr. Werner speaks of this ore in his translation of Cronstedt; it has been confounded with talc, and a person of the name of Dans exposed it to sale at Paris in the year 1784, under the name of green mica; it consists of small beautifully green crystals, or small brilliant scales. Mr. Foster discovered it in the mines of John Georgenstadt;

genstadt ; the green cupreous sand of Peru already mentioned, is perhaps referable to this ore.

4. Copper mineralized by sulphur, with scarcely any heat : this is called by the very improper name of vitreous copper ore ; it is of a deep violet grey, greenish brown, or liver colour ; it melts by a very gentle heat, is ponderous, sometimes flexible, and always yields to the knife ; in its fracture it appears brilliant like gold ; it is one of the richest ores of copper, as it affords about ninety pounds of metal per hundred weight.

5. Copper mineralized by sulphur, with more iron than the foregoing ; azure copper ore ; it does not differ from the preceding, but in the quantity of iron, which sometimes amounts to thirty pounds per quintal ; it affords no more than fifty or sixty pounds of copper per quintal, the rest being sulphur : these two ores are conveniently assayed by acids.

6. Copper mineralized by sulphur, with much iron ; brilliant or yellow pyrites. The quantity of sulphur and copper varies greatly in this mineral, the iron is always very abundant. It forms veins in the earth. This ore is sometimes massy, and of a dark colour ; it often appears scaly, and as it were micaceous ; in this form it is found in Denmark, Norway, Sweden, and St. Marie aux Mines, in France. Sometimes it is disseminated in its gangue, like the copper

copper of Alsatia ; this variety is often mixed with a small quantity of azure. The cupreous pyrites often present very brilliant blue, or violet colours at their surface, which are produced by the decomposition of their principles : they are then called chatoyant ores of copper, or ores resembling the peacock's tail ; they commonly contain a large quantity of sulphur, a small quantity of iron, and are not rich in copper ; such are the ores of Derbyshire, in England ; some of those of St. Bell, in Lyons, and many ores of Alsatia, such as those of Caulenbach and Feldens ; they adhere to every kind of gangue, rock crystal, quartzose spar, schistus, mica, &c.

7. Copper united to sulphur, arsenic, iron, and a small quantity of silver. This ore, called arsenical copper ore, or fahlerts, greatly resembles the grey silver ore, being only somewhat less brilliant, and differs merely from that, in containing a less quantity of silver. M. Romé de Lisle likewise distinguishes a white copper ore, which contains, according to him, rather more silver than the grey, but it is in reality a silver ore. The fahlerts commonly affords from thirty-five to sixty pounds per quintal.

8. Copper mineralized by sulphur and arsenic, with zink and iron ; brown or bloodose copper ore. M. Monnet found this ore only at Catherineberg, in Bohemia ;
it

it is brown, granulated, and very hard, and contains from eighteen to thirty pounds of copper per quintal.

9. Schistose copper ore. This consists of the vitreous copper ore, very intimately mixed in a brown or black schistus. It contains from six to ten pounds per quintal; chalk must be added in order to fuse it.

10. Bituminous copper ore. This consists of copper ore mixed with a kind of pitcoal, in Sweden.

11. Black copper ore, of the colour of pitch. Mr. Gellert denominates it copper ore in scoriæ; it is a residue of the decomposition of the yellow and grey copper ores, which contain neither sulphur nor arsenic, and approaches to the state of malachite; it has a black shining appearance like pitch.

12. Copper united to sulphur and arsenic, containing antimony: antimonial copper ore. Mr. Sage mentions this ore in his Elements of Mineralogy; it is grey and brilliant in its fracture, like antimony, and contains from fourteen to twenty pounds of copper in the quintal.

To assay an ore of copper, it must first be pounded and washed, and then roasted for a long time by a strong heat, and lastly, melted with four times its weight of black flux and marine salt; the button, which is often rendered black by a remaining portion of sulphur, must be melted with four parts of lead,
and

and cupelled, in order to separate the silver and gold it may contain; because there are few copper ores which do not contain a certain quantity of these precious metals. The flux of Mr. Tillet, which is a mixture of two parts of pounded glass, with one of calcined borax, and one eighth of charcoal, succeeds better for these reductions, than the black flux, because the latter forms a hepar, which dissolves part of the calx of copper.

Bergman advises the application of the vitriolic and nitrous acid, in the assay of these ores by the humid way; when the copper is dissolved by the acids, it is precipitated by iron.

In the large way copper ores are pounded, washed, and roasted in the open air, with scarcely any additional fuel, because the sulphur they contain burns of itself, as soon as it is well set on fire. When it is burnt out, the ore is roasted once or twice more with wood, and is melted in an open fire, into the substance called a mat of copper; the mat consists of copper which still contains a portion of sulphur: the fusions it is subjected to, serves to present new surfaces of the metal to the air, in order that it may be roasted with greater facility. After six or seven successive roastings, according to the quantity of copper the ore may contain, it is at last fused into black copper,

copper, which though malleable, still contains a portion of sulphur, which is not separated, but by the process for the extraction of the perfect metals it contains. The black copper is fused with three times its weight of lead, which is called refreshing the copper, and this mixture is cast in moulds, into the form of loaves, called loaves of eliquation. These are placed on two plates of iron, inclined in such a manner as to leave an opening between them at the bottom; the plates compose the upper part of the furnace of eliquation, whose bottom slopes forward; the fire made beneath the plates, heats the loaves; the lead melts and flows down among the coals, carrying with it the silver and the gold, with which it has a stronger affinity than the copper. After this operation, which is termed eliquation, the loaves are found considerably diminished in weight, and changed in figure; the heat is then raised, so that the copper may be nearly melted, in order that all the lead may be perfectly separated. The lead containing the perfect metals is carried to the cupelling furnace; and the copper is refined by melting in a crucible, where it remains a sufficient time to throw up, in the form of scoriæ, all foreign substances it may contain; it is examined from time to time, by immersing iron rods in it, which become coloured with a small

small quantity of copper, and its purity is judged by the brilliant redness of these specimens. Refined copper is cast into plates, or into rosettes; to form a rosette, the scoriæ which cover the copper in fusion, are carefully removed, and the surface of the metal is suffered to congeal. When it is no longer fluid, a wet broom is applied, the cold causes it to shrink, and a congealed portion of the metal not only detaches itself from the sides of the crucible, but from the rest of the melted metal, from which it is taken with tongs; the greatest part of the copper is, by repeating this operation, converted into rosettes; the portion which remains at the bottom is called the king.

Cupreous pyrites, which contain but a small portion of metal, are not worked but for the purpose of extracting sulphur and vitriol. At St. Bell, and in many other places they are roasted, and exposed to distillation, to separate the sulphur. During the roasting, a portion of the vitriolic acid re-acts on the metal, dissolves it, and begins to form vitriol. The roasted pyrites are afterwards exposed to the air. When the vitriolization is finished, the pyrites are lixiviated, and by evaporation of the filtered liquor, a salt, in blue rhomboidal crystals, called cupreous vitriol, blue vitriol, blue copperas, or Cyprian vitriol, is obtained. We shall speak
of

of this salt among the combinations of this metal.

Copper when heated, becomes coloured on its surface, nearly in the same manner as steel; the colours are blue, yellow, and lastly, violet; it does not melt till it is strongly ignited; when completely fused, it appears covered with a green flame, boils, and is volatilized, as may be observed in the chimnies of foundries. Flowers of copper are likewise found in the melting pots. If this metal be projected through flame, in small filings, it produces a blue and green colour, and from that property it is used in fireworks. If the melted metal be suffered to cool slowly, and, after the surface is become congealed, the fluid portion be poured off, the remaining solid part is found to be crystallized in pyramids; which are more regular and large, in proportion as the fusion has been more complete, and the cooling more gradual: its pyramids are quadrangular, and appear to be formed of a great number of octahedrons, inserted one in the other.

Copper heated with access of air, burns at its surface, and is converted into a calx of a dark red, in proportion as it absorbs the base of vital air: this calx may be easily obtained by heating a ball of copper to redness, which causes the calx to scale off. The same effect takes place, when red hot

copper is quenched in cold water; the sudden contraction of the parts of the metal, facilitating the separation of the portion of calx which covers the surface: this calx falls to the bottom of the water, and is called scales of copper. As it is not perfectly burnt, it may be calcined afresh in the muffle of the cupelling furnace; after which last process it is found to be of a deep brown colour; but by a violent heat it melts into a mass of a blackish or deep reddish brown colour. The calx of copper may be decomposed, and deprived of the base of air, which alters its metallic properties by oils, resins, &c. The scorixæ are partly reducible without addition, for the founders, who buy them of the copper-smiths, take no other trouble with them, than that of throwing them into large crucibles on the melted copper, with which they incorporate by fusion; the same method is used to melt the filings. The calx of copper appears to possess some saline properties, but its nature has not yet been ascertained.

The air attacks copper with greater or less facility, accordingly as the fluid is more or less loaded with moisture, and converts it into a rust, or green calx, which appears to have some saline qualities, viz. taste and solubility in water. From this circumstance the ancient chemists admitted the existence of a salt of copper. It is remarkable,

able, that this rust never attacks copper, except at the surface, and seems even to contribute to the preservation of the internal parts and masses of this metal, as may be seen in antique medals and statues, which are preserved very well beneath a covering of rust. The antiquarians call this crust patina, and set a high value on it, because it shews the antiquity of the pieces which are covered with it. Many artists, and in particular the Italians, know how to imitate this coating, and to counterfeit the antique bronzes.

The calcination of copper by humid air, appears to be produced by water in the state of extreme division; this fluid however does not appear to attack copper, nor decompose it like iron, at a high temperature. This metal seems to be more calcinable by cold water; it being a well known fact, that more danger attends the suffering of fluids to cool in copper vessels, than in making them boil: because, as long as the fluid is boiling, and the vessel hot, the aqueous vapour does not adhere to its surface; but when the vessel is cold, the drops of water which adhere to its sides, calcine it, and reduce it into green calx. The air and the cretaceous acid distributed therein, contribute, doubtless, greatly to this calcination; for by distilling this rust of copper

in the pneumato-chemical apparatus, I have obtained cretaceous acid.

Copper does not unite with earthy matters; its calx facilitates their fusion, and forms with them glasses of a deep brown.

Ponderous earth, magnesia, and lime, have no evident action on copper, and the action of these substances on the calces of that metal, is not known.

Caustic fixed alkalies digested in the cold with copper filings assume, at the end of a certain time, a light blue colour, the copper becoming covered with a powder of the same colour; these solutions are better effected in the cold than by the assistance of heat, according to Monnet. It is nevertheless essential to be observed, that this chemist made use of cretaceous vegetable alkali, instead of pure fixed alkali, which last appears to have a much stronger action on copper.

The volatile alkali dissolves this metal much more rapidly. The filings of copper digested with this salt, produce at the end of a few hours, a deep and most beautiful blue; the quantity of copper taken up is very inconsiderable. I have observed the phenomena of this solution for the space of a year in a small bottle. Caustic volatile alkali was poured on filings of copper; at the end of several months the surface of the metal was covered with a blue calx;
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the sides of the bottle were covered with a calx of a pale blue, and the lower part of the bottle which contained the copper, exhibited on the surface of the glass a brown calx, whose upper part was yellowish: this liquor loses its colour almost entirely when kept close, but it re-appears again when the bottle is opened. This phenomenon does not appear in a very evident manner, excepting at first, and when the solution is decanted from the copper; if the solution be old, and the copper still remains in it, its colour is of a beautiful blue, though in closed vessels; but on exposure to air it becomes deeper. By slowly evaporating this solution in the fire, greatest part of the volatile alkali is dissipated, the portion remains fixed with the calx of the metal, and is deposited in the form of soft crystals, as Monnet has observed. Mr. Sage affirms, that very beautiful crystals may be obtained by a slow evaporation, and has compared them to the natural azure of copper. The latter substance does not however afford volatile alkali when heated; is insoluble in water, and does not effloresce in the air like that prepared by art. M. Baumé affirms, that this compound affords very brilliant crystals, of a beautiful blue. The solution exposed to the air dries quickly, and leaves a grass green substance, which is merely a calx of copper. Mr. Sage

thinks that malachite is thus produced. But this calx does not afford cretaceous acid, as the earthy ore of copper does. If an acid be poured into the solution of copper by the volatile alkali, no precipitate is formed, but the blue colour disappears totally, and becomes converted into a very pale green. This phenomenon, which has been observed by Messrs. Pott and Monnet, shews that the quantity of calx of copper in volatile alkali is very small, and that it is re-dissolved by the acid, or by the ammoniacal salt, formed by the addition of the acid. The blue colour may however be made to appear again, by the addition of volatile alkali to the mixture. The calx of copper formed by fire, and every other calx of this metal, dissolves immediately in pure volatile alkali, which by this means may be made to take up a good quantity of the metal, a most beautiful colour being at the same time produced. From this property the volatile alkali has been proposed, as a test to discover the smallest portion of copper in all matters in which its existence may be suspected.

The vitriolic acid does not act on copper but when concentrated and boiling; much sulphureous gas is disengaged during the solution. A brown matter, of the consistence of a thick fluid, containing calx of copper, and a portion of the calx combined with
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the vitriolic acid, are found at the bottom; from which, by the addition of water and filtration, a blue solution is obtained: if this be evaporated to a certain point, and suffered to cool, rhomboidal long crystals are afforded, of a beautiful blue colour, called vitriol of copper: if the solution, instead of being evaporated, be left exposed a long time to the air, it affords crystals; but a green calx is precipitated. All the calces of copper when formed or dried in the air, are of this colour.

Vitriol of copper has a very strong styptic taste, approaching even to causticity; when exposed to heat it very soon melts, loses its water of crystallization, and becomes of a blueish white; a strong heat is required to separate the vitriolic acid, which adheres much more strongly to the calx of copper than to that of iron. Vitriol of copper is decomposed by magnesia and by lime; the precipitate formed by either of these substances, is of a blueish white, but becomes green if dried by exposure to air. Hence some chemists affirm, that the precipitates of vitriol of copper are green: the same is true of the precipitates obtained by fixed alkalies in the different states; being first blueish, and assuming a green colour as they dry. Mountain green may perhaps be formed in this manner. We must observe, that when vitriol of copper is precipitated

by the solution of cretaceous vegetable alkali, no effervescence is excited, which is a proof that the cretaceous acid unites readily with the calx of copper. All metallic solutions do not exhibit this phenomenon. Volatile alkali precipitates the solution of vitriol of copper in the same manner, of a blueish white colour; but the mixture very soon assumes a deep blue colour, because the volatile alkali dissolves the precipitate. A very small quantity of this salt is sufficient to re-dissolve all the calx of copper separated from the vitriolic acid.

The nitrous acid dissolves copper with great rapidity in the cold; a large quantity of very red nitrous gas being at the same time disengaged. This is the method used by Dr. Priestley, to obtain a very strong nitrous gas. A portion of the metal reduced to the state of calx, is precipitated in the form of a brown powder, and is separated by the filter. The filtrated solution is of a much deeper blue than the vitriolic solution, which shews that the copper is more perfectly calcined; by previous and careful evaporation, crystals may be obtained in cooling. Macquer is one of the first chemists who observed this property, in his Memoir on the solubility of salts in spirit of wine. If its crystals be formed very slowly, they have the figure of long parallelograms; if more quickly deposited, they

they are hexahedral prisms, with an obtuse point, irregularly disposed, and resembling bundles of divergent needles. Lastly, if this solution be too much evaporated, it affords only a magma, of an irregular form: which doubtless occasioned certain chemists to assert, that the solution was not susceptible of crystallization. Cupreous nitre is of a very bright blue, and is so caustic, that it may be employed in corroding the excrescences which arise on the skin; it melts, according to Mr. Sage, at the temperature of twenty degrees of the thermometer of Reaumur, and detonates on burning coals, though this phenomenon is scarcely sensible, on account of the large quantity of water it contains. When melted in a crucible it emits large quantities of nitrous vapour, which may be collected by distillation; when dried, its colour is green; an increase of the heat converts it to a brown, in which state it is merely a calx of copper. I have distilled this salt with the pneumatocchemical apparatus, and obtained much nitrous gas, a small quantity of cretaceous acid, and not a particle of pure air; it was converted into a brown calx by this operation. Nitre of copper attracts the moisture of the air, but it may be preserved a long time in close vessels. In a dry and hot air it becomes covered with a green efflorescence. It is very soluble in water, and rather

rather more so in hot than in cold water. The solution exposed to the air in shallow vessels, or quickly evaporated in hot and dry weather, leaves a calx of the same green colour as the crystals of the salt have in similar circumstances. It is precipitated by lime, and is then of a pale blue colour; by fixed alkalies of a pale blueish white; by volatile alkali in flocks of the same colour, which are very quickly re-dissolved, and produce a brilliant deep blue colour in the liquor; by liver of sulphur of a reddish brown colour, without an hepatic smell; and by tincture of nut-galls, of an olive green. The vitriolic acid likewise dissolves cupreous nitre, and blue crystals of vitriol are obtained, if the acid be used in a very concentrated state. Stahl observed this decomposition: M. Monnet has since confirmed it, and I have several times had occasion to make the same observation. Iron has a stronger affinity with most acids than copper. When a plate of iron is plunged in a solution of copper by the nitrous acid, the copper is precipitated in the metallic form, and covers the surface of the iron; this precipitation depends on the stronger affinity of the iron than of the copper to the base of air. The vitriol of copper exhibits the same phenomenon, and this process has been used by impostors to impose on the credulous.

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The muriatic acid does not dissolve copper, unless it be concentrated and boiling. The quantity of gas disengaged during this solution is but small, and its nature is not known; it seems, however, to be inflammable gas. The muriatic acid assumes a very deep and almost brown colour; the combination forms a magma very soluble in water; if it be lixiviated, the water becomes of a beautiful green colour, which distinguishes this solution from the two foregoing: when slowly and cautiously evaporated, and suffered to cool, it deposits prismatic crystals of a regular form; on the contrary, if the evaporation has been too rapid, and the cooling too sudden, it presents only very small sharp needles.

The muriate of copper is of a very agreeable grass green colour, its taste is caustic, and very astringent, and it melts by a gentle heat, congealing again into a mass when suffered to cool. M. Monnet affirms, that the muriatic acid adheres very strongly to it, and that it cannot be volatilized, without the assistance of a considerable heat. It strongly attracts the moisture of the air, and is decomposable by the same intermediums as the preceding salts of copper. I have observed, that the volatile alkali does not dissolve the calx of copper separated from the muriatic acid, so well as that which is separated

duces an inflammable gas by dissolving the copper. The residue was a mass of a blackish green, of which half was dissolved by the water, and communicated to it a green colour, which is a distinctive character of the muriate of copper; the other half exhibited a kind of calx of copper, formed by the muriatic acid. When this decomposition is repeated in the dose of four ounces of copper with two ounces of sal-ammoniac, in the common apparatus, Bucquet obtained two drachms eighteen grains of blue volatile alkaline spirit, which effervesced with acids, and contained about one cubic inch of cretaceous acid in the dram. This chemist was at a loss to determine whence the latter gas was produced, but I think it may arise from some impurities in the sal-ammoniac; for having repeated this experiment with sal-ammoniac purified by sublimation, I obtained a very caustic volatile alkali, which did not at all effervesce with acids. The calx of copper likewise decomposes sal-ammoniac, and affords a portion of cretaceous acid, together with the volatile alkali it disengages, which renders the latter effervescent. This alkali is always blue, because it carries up with it a small portion of the calx of copper, to which its colour is owing. Acids do not however precipitate this metal. Two medicines are prepared in pharmacy with sal-ammoniac and copper, of which the

the first has received the name of cupreous ammoniacal flowers, or *ens veneris*, and is nothing more than sal-ammoniac coloured by a small portion of calx of copper. A mixture of eight ounces of this salt, with one drachm of the calx of copper, is sublimed in two earthen vessels, the one placed on the other : all the sal-ammoniac is volatilized without being decomposed, and carries up a small quantity of copper, which gives it a blueish colour. The second, which is called *aqua celestis*, is prepared by suffering a pound of lime-water and an ounce of sal-ammoniac to remain in a copper vessel for ten or twelve hours ; the lime disengages the volatile alkali ; which dissolves a small quantity of copper of the bason, and produces the blue colour. The celestial water may be made in a glass or earthen vessel, if a small quantity of filings, or calx of copper, be added to the lime-water and sal-ammoniac.

Copper appears to decompose alum ; for if a solution of this salt be boiled in a copper vessel, a small quantity of clay is deposited ; and when the alum is precipitated by volatile alkali, its earth assumes a slight blue colour, denoting the presence of copper. This effect may likewise be attributed to the small excess of acid, which alum always contains.

Inflammable

Inflammable gas does not act on copper, but reduces its calces, by depriving them of the base of vital air, with which this gas has a stronger affinity than the copper.

This metal unites very readily with sulphur; the combination may be made in the humid way, that is to say, by mixing flowers of sulphur and copper filings together, with a small quantity of water; but it succeeds much better in the dry way. A mixture of equal parts of sulphur in powder and copper filings, are put into a crucible, which is heated by degrees, till it becomes red hot; the result is a mass of a blackish grey, a sort of mat of copper, which is brittle and more fusible than the copper itself. This compound is prepared for dying and painting on callicoes, by placing strata of plates of copper and sulphur in powder in a crucible, and heating it gradually, as we have observed. The kind of mat which is produced, is pulverized, and called *æs veneris*. Liver of sulphur and hepatic gas have a strong action on copper: the former dissolves the metal by the dry, as well as by the humid way; the second strongly colours the surface, but its effect has not yet been well examined into.

Copper forms alloys with many metals; with arsenic it becomes white and brittle, and forms white tombac; it unites with bismuth, and according to Gellert, forms
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alloy of a reddish white, with cubic facets.

It unites very readily with regulus of antimony, and affords a regulus, which is distinguished by a beautiful violet colour; it likewise decomposes antimony, and unites with the sulphur, which it takes from the regulus.

It combines very readily with zink. This combination may be made in two ways. First by fusion; a metal is produced whose colour resembles that of gold, and which is much less susceptible of rust than copper, though less ductile than that metal; the nearer its colour approaches to that of gold, the more brittle it is; and it varies greatly according to the proportion of the mixture, and the precautions used in melting it; its varieties are similar, Pinchbeck, princes-metal, Manheim gold. Secondly, by cementing plates of copper with lapis calaminaris reduced to powder, and mixed with charcoal; in a red heat, the copper unites with the zink, and forms brass: this is less susceptible of rust than copper, and is likewise more fusible, and less malleable. But a strong heat continued for a short time, deprives it of the zink with which it was united, and converts it into copper again.

Copper unites difficultly with mercury; though a sort of amalgam may be produced, by triturating copper in very thin leaves with mercury. A plate of this metal plunged in

a solution of mercury by the nitrous acid, becomes coated over with the semi-metal, precipitated by the copper.

Copper and lead unite very easily by fusion, as the formation of the leaves of eliquation prove.

Copper is combined with tin in two ways, either by applying melted tin on copper, or melting both metals together. The first operation is used in the tinning of copper, the second forms bronze. To tin copper vessels, they are first scraped, in order to render their surface clean and brilliant; after which they are rubbed with sal-ammoniac, to clean them more perfectly. They are then heated, and sprinkled with powdered resin; this substance covering the substance of the copper, prevents its calcination. Lastly, the melted tin is poured on, and spread about. It is with justice complained, that the tinning of copper vessels is not sufficient to defend them from the action of air, moisture, and saline substances, because these vessels are frequently observed to be covered with verdigris. It might be possible to remedy this inconvenience by a thicker covering of tin, if there were not reason to fear, that a degree of heat superior to that of boiling water, to which these vessels are often exposed, would melt the tin, and leave the surface of the copper uncovered. To prevent this
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last accident, the tin may be alloyed with iron, silver, or platina, to diminish its fusibility, and render it capable of being applied in thicker strata on the copper. Alloys of this kind are already used in several manufactures. The very small quantity of tin required to cover the surface of copper, is surprizing; Messrs. Bayen and Charlard having determined, that a vessel of nine inches in diameter, and three inches three lines in depth, did not gain more than twenty-one grains by tinning. This small quantity is nevertheless sufficient to prevent the dangers which might arise from the use of copper vessels, provided care be taken, that substances capable of dissolving the tin be not suffered to remain too long a time in the vessels; and more especially that the tin be frequently renewed: as the friction, heat, and action of spoons, with which the included substances are stirred, destroy it very quickly. There is likewise another cause of apprehension respecting the tin used by braziers in tinning, &c. It is often alloyed with one fourth of its weight of lead; and in this case the bad effects of the latter metal are much to be feared, as it is known to be very soluble in acids and fat substances. It is therefore necessary that government should take sufficient care that the braziers be not deceived in the tin they purchase, and that they may not employ

any but the Mallacca or Banca tin, in the state it is received in from the Indies, without having been alloyed or re-melted by the pewterers.

M. De la Folie, citizen of Rouen, well known by his chemical labours respecting the arts, and the useful discoveries with which he has enriched the arts of dying, of pottery, and a great number of manufactures at Rouen, proposed, in order to avoid the inconvenience and danger of tinning copper, that saucepans of forged iron covered with zink, might be used, which, as we have already seen, is not productive of any dangerous effects. Many persons have already used these vessels, and have been sensible of their advantages. It is much to be desired, that the use of these vessels may become more general.

When tin is melted with copper, a metal specifically heavier than the two metals employed, is obtained. This alloy is whiter, more brittle, and more sonorous, in proportion as the quantity of tin is greater. When it is very white it is called bell-metal; when it contains a larger proportion of copper, it is yellow, and is called bronze. This last is used in casting statues, and forming pieces of artillery, which require to be sufficiently solid not to burst, and not

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so ductile as to have their form destroyed by the stroke of bullets.*

Copper and iron are capable of uniting either by fusion, or in the way of soldering; yet this combination does not easily succeed. When a mixture of the two metals is melted in a crucible, the iron is found in pieces in the copper, without being perfectly united. Copper decomposes the mother water of martial vitriol, though iron has a stronger affinity with acids than copper.†

The uses of copper are numerous, and well known. The alloy of copper and zink is most commonly used on account of its great ductility and its beauty. As copper is a very violent poison, it ought never to be administered in medicine. The properest remedies in case of poisoning by copper reduced into calx or verdigris, are emetics, abundance of water, liver of sulphur, alkalies, &c.

* When the dose of tin exceeds that of copper, the metal becomes soft, but the specific gravity in almost every proportion of the two metals, is equal to, and in some cases exceeds, that of the heavier. T.

† This fact is well explained by Bergman, in his Treatise on Elective Attractions, § VI. The iron, in the mother water of martial vitriol, is dephlogisticated beyond a certain limit; or, according to the pneumatic theory, it is combined with a portion of the base of pure air. In this state it attracts the acid less than copper does. T.

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C H A P. XIX.

Concerning Silver.

SILVER, called Luna or Diana by the alchemists, is a perfect metal of a white colour, and of the most lively brilliancy; it has neither taste nor smell; its specific gravity is such, that it loses about the eleventh part of its weight by immersion in water, and a cubic foot of this metal weighs 720 pounds. Silver is so ductile, that it may be beat into exceedingly thin leaves, and drawn into wire much finer than a hair.* A grain of silver may be extended so as to form a vessel capable of containing an ounce of water. Its tenacity is so considerable, that a silver wire of the tenth of an inch in diameter, may sustain a weight of 270 pounds without breaking. Its hardness and elasticity are not equal to those of copper. It is the most sonorous of metals after those we have mentioned. It hardens under the hammer, but very readily loses that hardness by heating. Messrs. Tillet and Mongez have crystallized this metal, and obtained quadrangular pyramids, sometimes insulated like those which are found

* A grain of leaf silver measures somewhat more than 51 square inches, and the silver wire, used by astronomers, about the $\frac{7}{8}$ of an inch in diameter. This is about half the diameter of a fine human hair. T.

on the edges of the crucibles in which this metal has been melted, or grouped and laterally placed one on the other.

Silver is found in many various states in nature; the principal ores of this metal may be reduced to the following.

1. Native or virgin silver; it is known by its brilliancy and ductility, and is found in a great variety of forms; it is often in irregular masses, more or less considerable in magnitude. Sometimes it has the form of capillary threads twisted round, and in this state seems to have been produced by the decomposition of a red silver ore, as Henckel and Romé de Lisle have observed. It is likewise found in plates and in forms, which resemble the webs of spiders, and which the Spaniards for that reason call *arané*; in vegetation, or branches formed by octahedrons, inserted one in the other. Some of these specimens exhibit the mark of a leaf of fern, others are cubes and single octahedrons, whose angles are truncated; the latter are rare. Native silver is often dispersed in a quartzose gangue, and is sometimes met with in fat earths; it is found in Peru, in Mexico, and Kongsberg in Norway, at Johan Georgenstadt, and at Ehrenfriedensdorf in Saxony, at St. Marie at Allemont in Dauphiny, &c. This metal is not naturally found in the state of calx.

2. Native silver united to gold, copper, iron, arsenic, regulus of antimony, or to

gold and copper together, or to arsenic and iron together. These varieties of native silver alloyed, are found at Freyberg in Saxony, and in the mines of Guadalcanal in Spain; but it must be observed, that the foreign substances compose but a small proportion.

3. The vitreous silver ore is composed, according to most mineralogists, of silver and sulphur; it is of a blackish grey colour, resembling lead; some specimens are brown, greenish, yellowish, &c. and it may be cut with the knife. It is often amorphous, sometimes crystallized in octahedrons, and in hexahedral prisms, whose angles are truncated. M. Monnet distinguishes a variety, which instead of yielding to the knife like the others, became reduced into powder. This ore affords from sixty-two to eighty-four pounds of silver per quintal. It is very easily melted. If it be exposed to a heat not sufficient to melt it, the sulphur is dissipated, and virgin silver in vegetation, or fibres, is obtained.

4. The red silver ore is often of a deep colour; sometimes transparent, crystallized in cubes, whose edges are truncated, or in hexahedral prisms, terminated by tetrahedral pyramids; at Potosi it is called Rossi-clero. The silver is combined with sulphur and arsenic; when it is broken, its colour appears lighter within, and its structure resembles
small

small needles, or convergent prisms, like stalactites. If it be exposed to a fire carefully managed, and capable of igniting it, the silver is reduced, and forms capillary vegetations, similar to native silver. It affords from fifty-eight to sixty-two pounds of silver per quintal. The varieties of this species differ in colour, in form, in weight, &c. They are in general found in all places where the other ores of silver are met with.

5. Silver with arsenic, cobalt, and iron mineralized by sulphur. Bergman affirms, that the silver is sometimes fifty hundredths in this ore. The ore is sometimes grey and brilliant, often of a dull and tarnished colour, with efflorescences of cobalt. The goose dung ore belongs to this species.

6. Grey silver ore, which differs no otherwise from the copper ore, called falherz, than in containing a larger proportion of this precious metal; it is well crystallized in triangular masses, whose edges are cut slopewise. The largest of these crystals have scarcely any brilliancy; the smallest dispersed on a flat gangue, form a very agreeable appearance when exposed to the light, on account of their great brilliancy. The grey silver ore affords from two to five marks of silver per quintal. This ore is sometimes found in organic matters, whose form it perfectly imitates; it is then called
figurate

figurate ore of silver; such is the ore which resembles the blades of corn, and that which M. Romé de Lisle observed in the form of cones of the pine. Wood has likewise been found mineralized by this species of ore. The grey silver ore contains silver, copper, iron, arsenic, and sulphur; when the iron is in small proportion, it is called white silver ore. This last must not be confounded with galena, containing silver, which the workmen sometimes call silver ore.

7. Black silver ore, called nigrillo by the Spaniards, is nothing more, according to Lehman and Romé de Lisle, than a decomposition of the red or grey silver ore, or a sort of middle state between these ores and native silver; it is often met with. The latter mineralogist observes, that the solid, spongy, or porous specimens, are produced by the earth and vitreous ore, and are much richer than those specimens which are friable, and of a pitchy colour, whose origin is owing to the alteration of white or grey silver ores. From these causes it is very subject to vary in the quantity of its product; in general it affords from six or seven pounds to near sixty pounds per quintal.

8. Corneous silver ore, or the natural combination of silver with the muriatic, and a small quantity of vitriolic acid, is of a dirty yellowish grey, sometimes it is of a fawn colour;

colour; it is rarely transparent; easily yields to the knife, and melts by the flame of a candle. It is found crystallized in cubes, but most commonly in irregular masses. Portions of native silver are frequently found inserted in its mass. It was formerly thought to contain sulphur and arsenic, but mineralogists at present are agreed respecting its nature. M. Cronstedt, Lehman and Sage, Woulf, Lommer and Bergman, distinguished the presence of the marine acid, which is disengaged by heat. M. Woulf likewise discovered, that it contains the vitriolic acid; it is found in Saxony, at St. Marie, at Guadalcanal in Spain, and at Allemont in Dauphiny.

9. The soft silver ore of Wallerius, is native or mineralized silver, interspersed in greater or less quantities, in coloured earths. Many varieties of colour are observable in earths containing silver, from the dirty grey to the deep brown.

10. Lastly, silver is found often combined with other metallic matters, in the ores we have described; such as mispickel, the grey cobalt ore, kupfer-nickel, or ore of nickel, antimony, which often presents the variety called plumose silver ore, blend, galena, martial pyrites, and white copper ores: these last are of the species of grey silver ores. All these substances frequently contain a sufficient quantity of silver to be worked

worked with profit; but it is easy to conceive, that they ought not to be described like the foregoing, as proper ores of silver, and that it is sufficient to remark, that they are partly composed of this metal.

The assay of silver ores varies according to their nature; such as contain native silver ore, require in strictness nothing more than separating and washing. Trituration with running mercury may be used for the accurate separating of this metal from the marine substances, which change it; the fluid metal dissolves the silver, and may be afterwards driven off by fire. Sulphureous silver ores require to be roasted, and afterwards melted with a greater or less quantity of flux; in this fusion, silver is obtained commonly alloyed with lead, copper, iron, &c. For the separation and accurate ascertaining of the quantity of precious metal contained in this alloy, a process entirely chemical is used, which depends on the properties of the imperfect metals. Lead being capable of vitrifying, and of carrying with it, in its vitrification, the imperfect metals, such as iron and copper, without acting on silver, this property is used to separate the perfect metal from those with which it is alloyed; the silver is melted with a quantity of lead, which must be so much the more considerable in proportion as the quantity of base metal is supposed to be greater;

greater. This alloy is then put in flat and porous vessels, made of calcined bones and water; this kind of crucible, which is called a cuppel, is well adapted to absorb the glass of lead, which is formed in the operation of cuppellation. After this process the silver remains pure. In order to determine what quantity of imperfect metal it contains, or its degree of fineness, the mass of silver is supposed to be divided into twelve parts, called penny-weights, and each of these penny-weights into twenty-four grains; if the mass of silver has lost a twelfth of its weight, it is called silver of eleven penny-weights fine; if it has lost only a twenty-fourth, it is called silver of eleven penny-weights, twelve grains fine, and so forth. The cuppel, after this operation, is found to be much heavier, and contains the glass of lead, and those imperfect metals, which were united with the silver, and have been separated by the lead. As the lead itself almost always contains a small quantity of silver, it is necessary first to cuppel it by itself, in order to determine the quantity of the silver it contains, and a deduction must be made, from the button of fine silver obtained, of the small portion known to be contained in the lead made use of, which is called the witness. Cuppellation, is attended with a phenomenon by which the artist is advertised of the state of the

the process as it goes forward. In proportion as the silver becomes pure, by the vitrification and separation of the lead, it appears much more brilliant than the portion which is not yet fine; the brilliant part increases by degrees, and when all the surface of the metal becomes pure and luminous, the instant in which it passes to this state, exhibits a flash or fulguration, which denotes that the operation is finished. Cupelled silver is very pure with respect to the imperfect metals it may have contained, but it may contain gold; and as it always contains a certain quantity, another operation must be made to separate these two perfect metals. As gold is much less changeable than silver, by most solvents, the silver is dissolved by the addition of the nitrous or muriatic acids, or by sulphur; and the gold, on which these solvents have little or no action, remains pure. This method of separating silver from gold is called parting; we shall speak of the different kinds of parting, after having described the action of each of the solvents on silver, when we shall speak of the alloy of this metal with gold.

The large works where silver is extracted from its ores and purified, are similar to those we have described for the assay of the ores of this metal. There are, in general, three methods of treating silver in the large way: the first consists in tritulating
virgin

virgin silver with mercury; this amalgam is washed to separate all the earth, the superfluous mercury is pressed out through the pores of bags of leather, and the rest is separated by distillation in iron retorts; after which the silver is melted and cast into ingots. This process cannot be used with silver ores that contain sulphur: these are roasted and mixed with lead, to refine the precious metal by cupellation. Rich silver ores are treated in this manner, but the poorer ores are treated in a different manner from the two foregoing; they are melted without previous roasting, with a small quantity of pyrites. This fusion, which is called the crude fusion, affords a mat of copper in combination of silver, which is treated with lead in the way of eliquation; the latter, which carries down the silver during the fusion, is afterwards scorified on the cupel, and the perfect metal remains pure. Cupellation in the large way differs from that which is made in the small way; in this circumstance, viz. that in the first, the scorified lead is driven off by the action of a bellows, whereas, in the latter, the glass of lead is absorbed by the cupel.

The silver obtained by the processes here described is, in general, much less liable to alteration than all the metals hitherto described. The contact of light does not at all change this metal, however long it be exposed

exposed to it; heat melts it, causes it to boil, and to become volatilized, but without alteration. It does not melt in less than a white heat, but is more fusible than copper. When it has been held in fusion for a certain time it boils and emits vapour, which consists of silver volatilized. This fact is proved by the existence of the metal in the funnels of chimnies, under which large quantities are continually melted. It is likewise confirmed by the capital experiment of the Academicians of Paris, who exposed very pure silver to the focus of Trudaine's lens. These philosophers observed, that the melted metal emitted a thick fume, which completely silvered a piece of gold held over it.

Silver, when slowly cooled, is capable of assuming a regular form, and crystallizes in quadrangular pyramids. M. Baumé has observed that this metal, in cooling, assumes a symmetrical form, which is observable on its surface by small fibres, resembling the feather of a pen. I have observed that the fine button obtained by cuppellation often presents on its surface small spaces of five or six sides arranged among each other, like a pavement; but the crystallization in tetrahedral pyramids, has not been well observed, except by Messrs. Tillet, and the Abbé Mongez.

It has been long thought, and some chemists still are of opinion, that silver is indestructible.

destruſtible by the combined action of heat and air. It is certain that this metal kept in fuſion without contact of air, does not appear to be ſenſibly altered; yet Junker had affirmed, that by treating it a long time in the reverberatory furnace, in the manner of Iſaacus Hollandus, ſilver was changed into a vitreous calx. This experiment has been confirmed by Macquer. That learned chemiſt expoſed ſilver twenty ſucceſſive times in a porcelain crucible to the fire of the furnace at Sèvres, and at the twentieth fuſion he obtained a vitriform matter of an olive green, which appeared to be a true glaſs of ſilver. This metal when heated in the focus of the burning glaſs, has always exhibited a white pulverulent matter on its ſurface, and a greeniſh vitreous covering on the ſupport it reſted upon. Theſe two facts remove all doubt reſpecting the alteration of ſilver; though it is much more difficult to calcine than other metallic matters, yet it is capable of being converted after a length of time into a white calx, which treated in a violent fire, affords an olive-coloured glaſs. It may perhaps be poſſible to obtain a calx of ſilver, by heating this metal when reduced into very fine laminæ, or in leaves, for a very long time in a matraſs, as is done with mercury. At all events it is certain, that ſilver does not combine with the baſe of vital air without great difficulty, and

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that heat does not favour this combination in the same manner as it does with almost all the other metals; but on the contrary, disengages that principle from it very readily: for the calces of silver are all easily reduced without addition, a circumstance which depends on the slight adherence of the oxygenous principle, which by heat is disengaged in the form of vital air.

Silver is not changed by the action of air, its surface being scarcely tarnished by a very long exposure to that fluid. Water does not act on it. Earths do not combine with it, but it is probable that its calx would give an olive green colour to glasses with which it might be fused.

The salino-terrestrial matters and the alkalies, do not sensibly act on silver. Vitriolic acid dissolves it when very concentrated or boiling, and the metal is greatly divided. Much sulphureous gas is disengaged during this solution; the silver is converted into a white matter, on which spirit of vitriol must be poured, in order to hold it in solution: very small needles of lunar vitriol are obtained by evaporating this liquor. I have several times obtained vitriol of silver in plates, formed by the union of these needles length-wise. This salt melts in the fire, and is very fixed; it is decomposable by alkalies, iron, copper, zinc, mercury, &c. All the precipitates obtained
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by alkalies, are reducible without addition, and become converted into fine silver, in closed vessels.

The nitrous acid dissolves silver with rapidity, and even without the assistance of heat. This solution is sometimes performed so quickly, that in order to prevent the inconvenience that might arise, it is necessary to use silver in a lump. A large quantity of nitrous gas is disengaged, and a white precipitate, more or less abundant, is formed, if the spirit of nitre contained a portion of vitriolic or muriatic acid. The spirit of nitre usually becomes of a blue or green colour, but loses this colour, and becomes transparent as soon as the solution is finished, if the silver made use of be pure; but on the contrary, a greenish tinge remains when the silver contains copper. The purest silver which can be employed, sometimes contains gold: in this case, as the nitrous acid has scarcely any action on this perfect metal, this last is separated in the form of blackish flocks, in proportion as the silver is dissolved. From the difference of the action of this acid on these two metals, it is successfully employed in separating them from each other, in the operation of parting by aquafortis. The nitrous acid dissolves more than half its weight of silver: this solution is exceedingly caustic, tinges the epidermis of a black colour, and entirely corrodes it.

When highly charged with the metal, it deposits slender brilliant crystals, resembling those of sedative salt; when the one half is evaporated, it affords, by cooling, flat crystals, which are either hexagonal, or triangular, or square, and appear to be formed of a great number of small needles, placed one beside the other. These plates are placed obliquely on each other; they are transparent, and very caustic, and are called nitre of silver, lunar nitre, or lunar crystals. Lunar nitre is quickly altered by the contact of light, and blackened by combustible vapours. It detonates on heated charcoal, and leaves a white powder, which is pure silver. It is very fusible: if it be exposed to heat in a crucible, it first swells up and loses the water of crystallization, after which it remains in fusion; and if suffered to cool in this state, it appears to be a grey mass, and forms a preparation known in pharmacy and surgery, by the name of lapis infernalis. It is not necessary in making this preparation, to use the crystals of lunar nitre, which are difficult and expensive to obtain; as it is sufficient to evaporate a solution of silver in the nitrous acid to dryness, and to put this residue in a crucible or silver ladle, as M. Baumé advises, and to heat it slowly till it is in an undisturbed fusion, in which state it must be poured into a mould, to give it the form of small cylinders. If the cylinders of lapis infernalis be broken, they
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are found to be of a needle-formed texture, radiating from the axis of each cylinder. Lunar nitre must not be too long heated to make the lapis infernalis, as by that means a part of the salt would be decomposed, and a button of silver would be found at the bottom of the crucible. To ascertain what passes in this operation, I have distilled lunar crystals in the pneumato-chemical apparatus: they afforded nitrous gas, and a large quantity of very pure vital air; the silver was recovered in the matrafs, intirely reduced. The glass was opake like enamel, and of a beautiful marron brown colour. The brown colour of the glass in this experiment, doubtless arises from manganese, or some other substance contained in it; for the colour of glass formed by the calx of silver, is of an olive green, as we have already observed.

Lunar nitre exposed to the air, does not attract moisture; it is very soluble in water, and may be crystallized by the slow evaporation of that fluid.

The nitrous solution of silver is decomposed by the salino-terrestrial substances and by alkalies, but with very different phenomena, according to the state of the substances. Lime-water forms a very abundant olive-coloured precipitate; cretaceous fixed alkalies precipitate it of a white colour; the caustic volatile alkali of a green, inclining

to olive: the latter precipitation takes place after a considerable time.

Though the nitrous acid acts with more energy than any other on silver, it has not the strongest adhesion and affinity with that metal. The vitriolic and muriatic acids are capable of depriving it of the calx of silver which it may hold in solution. Hence it is, that a few drops of these acids poured into a nitrous solution of silver, produce a precipitate of a white powder when the vitriolic acid is used, or a thick coagulum when the muriatic acid is used. In the first case vitriol of silver is formed; in the second, muriate of silver. These two salts not being very soluble, are precipitated. It is not necessary to use the vitriolic and muriatic acids in a disengaged state, to produce these decompositions; the neutral salts resulting from their union with alkalies and earthy matters, may be employed with equal advantage. A double decomposition or combination then takes place, because the nitrous acid being separated from the silver, unites with the base of the vitriolic and muriatic salt. This difference of affinity between the acids and silver, is the basis of a process used for procuring the nitrous acid in a state of purity, without any mixture of other acids; such in a word as is necessary for many operations in metallurgy, and for the most part of chemical researches. As it seldom happens in
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the distillation of spirit of nitre, that this fluid is not mixed with a certain quantity of vitriolic and muriatic acid, chemists have endeavoured to discover methods of separating these several fluids, and they avail themselves with success of the nitrous solution of silver for this purpose. The lunar solution is poured into the impure nitrous acid, till no more precipitate is formed. The deposition formed by the vitriol of silver, or lunar cornea, is suffered to subside; the acid is decanted and distilled by a gentle heat, to separate it from the small portion of lunar salt it may contain; and the product is very pure nitrous acid, called precipitated nitrous acid.

Most metallic matters are capable of decomposing the nitrous solution of silver, because they have a stronger affinity than that metal with the nitrous acid. The neutral arsenical salt dissolved in water, produces a reddish precipitate in the nitrous solution, which consists of silver united with arsenic; this precipitate resembles the red ore of silver. Silver may be precipitated in its metallic state by most metals and semi-metals; but we shall more particularly attend to the separation of this perfect metal by mercury or by copper, because of the phenomena the first presents, and the utility of the latter.

Silver separated from the nitrous acid by mercury, is in its metallic state, and the

slowness of its precipitation produces a peculiar symmetrical amalgam, known by the name of *Arbor Dianæ*, or the philosophical tree. There are many processes for obtaining this crystallization. Lemery directs one ounce of fine silver to be dissolved in nitrous acid of moderate strength: this solution is to be diluted with about twenty ounces of distilled water, and two ounces of mercury are to be added: in forty days a very beautiful vegetation is formed. Homberg has prescribed a much shorter process: according to this chemist, an amalgam of four drams of leaf silver, with two drams of mercury, must be made in the cold. This amalgam is to be dissolved in a sufficient quantity of nitrous acid, and a pound and a half of distilled water must be added to the solution. A little ball of the soft amalgam of silver must be put into an ounce of this liquid, and the precipitation takes place almost instantly. The precipitated silver, united to a portion of the mercury, disposes itself in fibres of a prismatic appearance on the surface of the amalgam: other fibres appear, and insert themselves in the foregoing, so as to exhibit a vegetation in the form of a bush. Lastly, M. Baumé has described a method of obtaining the *Arbor Dianæ*, which differs in some respects from that of Homberg, and succeeds with greater certainty; he directs six drachms of the
solution

solution of silver, and four of the solution of mercury, in the nitrous acid, both well saturated, to be mixed, and five ounces of distilled water to be added to this liquor. The mixture must be poured into an earthen vessel, upon six drachms of an amalgam of silver, made with seven parts of mercury, and one part of silver. These two methods succeed much more quickly than that of Lemery, by the reciprocal action and affinity between the metallic substances. In fact, the mercury contained in the solution, attracts that of the amalgam; the silver contained in the latter acts likewise on that which is held in solution, and from these attractions, a quicker precipitation of the silver takes place. The mercury which composes a part of the amalgam, being more abundant than is necessary to precipitate the silver from the solution, produces likewise a third effect of considerable importance; it attracts the silver by the affinity and tendency it has to combine with that metal, and it effectually combines with it; since the vegetation of the *Arbor Dianæ* are a true brittle amalgam of a crystallized form. This crystallization succeeds much better in conical vessels, or glasses, than in round or open vessels, such as the cucurbit recommended by M. Baumé. It may likewise be observed, that it is necessary to place the vessel in which the experiment is made, in a situation where

where it may not be shaken, or agitated, as such circumstances would effectually prevent the symetrical arrangement of the amalgam.

Copper plunged in the solution of silver, precipitates this metal likewise in a brilliant and metallic form. This process is usually employed to separate the silver from its solvent, after the process of parting. Plates of copper are immersed in the solution, or the solution itself is poured into a vessel of copper; the silver immediately becomes separated in whitish grey flocks. When the liquor becomes blue, and is deprived of all its silver, it is decanted off; the silver, after being washed several times in water, is melted in a crucible, and cupelled, in order to separate it from the portion of copper with which it united during the separation. The silver afforded by this operation, is the purest of all; it is twelve penny-weights fine. From these two precipitations of silver by mercury and copper, we see, that metals separated from their solvents by other metallic matters, are precipitated with all their properties. This phenomenon depends, as we have observed in the history of copper, on the circumstance that the metals, immersed in the solution of silver, take the oxygenous principle from the latter, by virtue of their stronger affinity.

The muriatic acid does not immediately dissolve silver, but it perfectly dissolves its calces. When this acid is surcharged with the

the oxygenous principle, and in the dephlogisticated state, it readily dissolves that metal. This no doubt accounts for what happens in the process of dry parting. The operation consists in exposing plates of gold alloyed with silver to heat in a cement, composed of a mixture of martial vitriol and common salt: the vitriolic acid disengages the muriatic acid, gives it a portion of its oxygenous principle, and the latter acts on, and dissolves the silver.

A much shorter and easier process is used to combine the muriatic acid with the calx of silver, by pouring it into a nitrous solution of the metal. The very abundant precipitate, which is instantly formed, is a combination of the muriatic acid with silver, which has a stronger affinity with this acid than with that of nitre, and consequently quits the latter to unite with the former. The same combination is obtained by pouring the muriatic acid into a solution of vitriol of silver, because this has a stronger affinity than the vitriolic acid with the metal. The muriatic acid may likewise be combined with silver, by heating it on a calx of the metal precipitated from the nitrous acid by fixed alkali.

The muriate of silver possesses many properties which deserve to be known; it is fusible, that it melts when exposed in an apothecary's phial to a mild heat; as for example,

example, that of hot ashes. By this fusion it is converted into a grey and semi-transparent substance, resembling horn, and for that reason has been called luna cornea. If it be poured on a stone, it becomes fixed in the form of a friable matter, crystallized as it were in fine silvery needles. When heated for a long time with contact of air, it is decomposed; it passes easily through the crucibles; part is volatilized, and part is reduced into metal, affording globules of silver, interspersed among the portion of the luna cornea, which is not yet decomposed. Luna cornea exposed to light, loses its white colour, and becomes brown in a short time. It dissolves in water, in but a very small quantity; a pound of distilled boiling water taking up only three or four grains, according to the experiment of M. Monnet. Alkalies are capable of decomposing luna cornea dissolved in water, or in the dry way by heat; this method affords the purest and finest silver known. A mixture of four parts of vegetable alkali, or chalk of pot-ash, with one part of luna cornea, is melted in a crucible: when it is in strong fusion, it is taken from the fire, suffered to cool, and broken; the silver is found beneath the muriate of pot-ash formed in the operation, and the super-abundant portion of alkali employed. M. Baumé, the inventor of this process, affirms, that the quantity of alkali he directs, prevents the
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the luna cornea from passing through the crucible, by acting on all its parts, which it decomposes at once. Margraaf has given another process for reducing luna cornea, and obtaining perfectly pure silver: five drachms sixteen grains of luna cornea are triturated in a mortar, with one ounce and a half of concrete volatile alkali, or ammoniacal chalk, a sufficient quantity of distilled water being added to form a paste; this mixture is agitated till the swelling and effervescence, which are excited, have subsided. Three ounces of purified mercury are then added, and triturated, till a perfect amalgam of silver is obtained: this is washed with a large quantity of water, the trituration still being continued, and the washing renewed, till the water passes off very clear, and the amalgam is very bright. The amalgam being then dried and distilled in a retort, till the vessel has acquired a white heat; the mercury passes into the receiver, and the silver is found pure at the bottom of the retort. In this way the metal is obtained in the most perfect state of purity, and without any sensible loss. This is the silver which ought to be used in the nicer chemical experiments. The water employed in washing the mixture carries off two substances; a certain quantity of sal-ammoniac, which it holds in solution, and a white insoluble powder. When the latter is sublimed, a small quantity

quantity of silver is found at the bottom of the sublimatory vessel. This experiment shews, that luna cornea is not completely decomposed, unless by the double affinity. In fact, in the process of Margraaf, the volatile alkali does not unite with the muriatic acid, but because the silver combines on its part with the mercury, which attracts and tends to separate it from the acid, which the alkali alone could not do. It is easily seen, that this long and expensive operation can only be used in the small works of a chemical laboratory. If luna cornea in large quantities be required to be reduced, either fixed alkalies, or some metallic substance, must be used, which have a stronger affinity than silver with the marine acid; such, among others, are the regulus of antimony, lead, tin, iron, &c. If one part of luna cornea be melted in a crucible with three parts of one of these metals, the silver will be found reduced at the bottom of the crucible, and the metal united to the muriatic acid. Silver precipitated in this manner, is very impure, and always contains a portion of the metal used for the reduction; and as lead is most commonly employed, according to the advice of Kunkel, the silver obtained requires to be cupelled; it cannot consequently be brought to the same state of purity with the silver reduced directly by alkalies, or by the process of Margraaf.

Aqua

Aqua regia acts strongly on silver, and precipitates it in proportion as it is dissolved: this effect may easily be understood; the nitrous acid first dissolves the metal, and the muriatic acid seizes it, forming luna cornea, which falls down on account of its small degree of solubility. This process may be used to separate silver contained in gold.

The action of the other acids on silver are not well known; it is only known that a solution of borax produces a very abundant white precipitate from the nitrous solution of this metal, and that this precipitate consists of the sedative acid united to a portion of the calx of silver.

This metal does not appear to be altered by neutral salts; it is certain that it does not detonate with nitre, nor decompose sal-ammoniac. This unchangeableness of silver with nitre, affords a good method of separating it from the imperfect metals with which it may be united, such as copper, lead, &c. The alloyed metal must be melted with the addition of nitre; the salt detonates and burns the portion of foreign imperfect metal, and the silver remains at the bottom of the crucible, in a state of much greater purity than before.

Almost all combustible matters have a certain action on silver; no metal is more quickly tarnished and coloured by inflammable matters; hepatic gas, from whatever substance

substance it may be disengaged, communicates to it immediately upon contact, a blue or violet colour, inclining to black, and greatly diminishes its ductility. It is well known that hepatic animal vapours, such as those of necessary houses, putrefied urine, and hot eggs, produce the same effect on this metal. The mutual action of these two bodies, and the kind of combination which arises from them, has not yet been examined into.

Sulphur combines readily with silver; this combination is usually made by stratifying plates of the metal with flowers of sulphur in the crucible, and quickly fusing the mixture: a deep violet coloured mass is produced, much more soluble than silver, brittle, and disposed in needles; in a word, a true artificial ore. This combination is easily decomposed by the action of fire, because of the volatility of the sulphur and the fixity of silver; the sulphur is consumed and dissipated, and the silver remains pure; liver of sulphur dissolves this metal in the dry way. When one part of silver is melted with three parts of liver of sulphur, the metal disappears, and becomes soluble in water, together with the hepar. If an acid be poured into this solution, a black sulphureous precipitate of silver is obtained. Silver left in liquid liver of sulphur, quickly assumes a black colour, and the sulphur appears to quit the alkali to unite with, and mineralize

mineralize the metal, as we have likewise observed it does with mercury.

Silver unites with arsenic, which renders it brittle; but the action of the arsenical acid on this perfect metal, is not yet known.

It does not combine with cobalt without difficulty.

It unites perfectly easily with bismuth, and forms a brittle mixed metal, whose specific gravity is greater than that of the two metals separately taken. According to Cronstedt, silver does not unite with nickel; but when these metals are melted together, they remain beside each other, as if their specific gravity were precisely the same.

It mixes by fusion with regulus of antimony, and affords a very brittle alloy. It seems capable of decomposing antimony, and of uniting with the sulphur of that mineral, with which it has a stronger affinity than the regulus of the antimony.

Silver combines readily with zink by fusion; alloy is produced by this combination, granulated at its surface, and very brittle.

It dissolves completely, and even without heat, in mercury. To produce this solution, silver leaf may be triturated with the metallic fluid; an amalgam is immediately produced, whose consistence varies according to the relative quantities of the two substances. This amalgam is capable of assuming a regular

gular form ; by fusion and slow cooling, it affords tetrahedral prismatic crystals, terminated by pyramids of the same form. The mercury assumes a degree of fixity in this combination ; for a much stronger heat is necessary to separate it from the silver, than would be required to volatilize it alone. Silver is capable of decomposing corrosive sublimate either by the dry or the humid way.

It unites perfectly with tin, but loses its ductility by the smallest addition of this metal.

It readily becomes alloyed with lead, which renders it very fusible, and deprives it of its elasticity and sonorous quality.

It unites with iron, and forms an alloy, which has been but little examined into, but may probably become of the greatest utility in the arts.

Lastly, it melts and combines in all proportions with copper ; the latter does not deprive it of its ductility, but renders it harder and more sonorous, forming an alloy which is often employed in the arts.

Silver is a metal highly useful, on account of its ductility, and its indestructibility by fire and by air. Its brilliancy renders it capable of serving the purposes of ornament. It is applied on the surface of different bodies, and even on copper ; and likewise enters into the texture of rich silks ; but its most considerable use is that of affording
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ing a matter, proper by its hardness and ductility, to form vessels of all sorts. Silver plate is usually alloyed with one twenty-fourth of copper, which gives it a greater degree of hardness and coherence, and does not render it at all noxious, because the twenty-three parts of silver cover the copper, and intirely prevent its noxious effects.

Lastly, silver is employed as a medium of exchange, in the form of money; in this case it is alloyed with one twelfth part of copper, and is consequently eleven penny-weights fine.

C H A P. XX.

Concerning Gold.

GOLD, or sol of the alchemists, is the most perfect and the least changeable metal known; it is of a yellow brilliant colour: no other substance in nature is so heavy, for it loses only between one nineteenth and one twentieth of its weight in water.* Neither its hardness nor its elasticity are very considerable. Its astonishing ductility, which are well ascertained by the smallness of gold wire, and the thinness of gold leaf, is such, that an ounce of this metal is suffi-

Z 2 cient

* Platina is much heavier. See the note at the end of that article. T.

cient to gild a silver wire of 444 leagues in length, and it is reduced into plates sufficiently thin to be blown away by the wind. A grain of gold, according to the calculation of Lewis, is capable of covering the surface of more than 1400 square inches. It is the most tenacious of all the metals. A gold wire of one tenth of an inch in diameter, being capable of sustaining a weight of 500 pounds without breaking. Gold soon becomes hard under the hammer, but immediately recovers its ductility by ignition.

The colour of gold is susceptible of considerable variety; it is more or less yellow, and some specimens are almost white; these differences however seem to depend on some alloy. Gold has neither smell nor taste; it is capable of crystallizing by cooling, in short quadrangular pyramids, as Messrs. Tillèt and Mongez have observed.

Gold is almost always found in a native or virgin state: it is sometimes met with in small insulated masses, disposed on a matrix of quartz; sometimes it is in small spangles, intermixed with sand at the bottom of waters; and lastly, it is obtained from many ores into the composition of which it enters, such as galena, blend, red silver ore, and virgin silver. It is almost always united with a certain quantity of silver and other metals, forming natural alloys.

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There are many varieties of native gold, in plates, in grains, in octahedral crystals, in four sided prisms, striated in filaments, and in irregular masses. Mr. Sage thinks, that native gold in prisms is united to a certain quantity of mercury, which renders it brittle.

Modern mineralogists admit several species of gold ores.

1. Native gold united to silver, copper, iron, &c. found in Peru, Mexico, Hungary, Transylvania, &c.

2. The auriferous pyrites: it is not easily distinguished by the eye from other pyrites; the gold is separated by treating the ore with the nitrous acid, and washing the residue. The gold seems to be merely mixed with martial pyrites. Certain arsenical pyrites, and in particular those of Salsberg, in Tyrol, likewise contain a small portion of gold.

3. Gold mixed with silver, lead, or iron, mineralized by sulphur. This auriferous ore is of a very compounded nature according to Mr. Sage; it consists of blend, galena, specular antimony, copper, silver, and iron; the gold melts and issues out with the lead when the mass is exposed to heat; it comes from Nagaya in Transylvania.

The method of assaying ores of gold, differs according to the nature of the mineral; pulverizing and washing are sufficient for the separating of native gold from its matrix;

if the gold be alloyed with other metals, it will be necessary to roast the ore, and the metal, after being extracted by fusion, must be cupelled with lead, and parted with aqua fortis.

The method of extracting gold from its ores may be easily understood, from the consideration of the metallurgic processes we have already described. Native gold requires only to be separated from its gangue; for this purpose it is ground, and afterwards washed; it is then triturated in a mortar, filled with water, together with ten or twelve parts of mercury: the water which washes the metallic substance, and separates those parts which are merely earthy, must be decanted off. When the amalgam formed in this operation is thus deprived of all its earth, and appears very pure, it is pressed in bags of shamoy leather; a great part of the mercury passes through the pores of the skin, and the gold remains united with a certain portion of the semi-metal. The remaining mercury is separated by distillation from the amalgam, and the pure gold being fused, is cast into bars or ingots. The gold which is found combined in the ores of other metals, such as those of lead and copper, is extracted by cupellation and parting from the former of these metals; and from the latter it is obtained by eliquation with lead, which

which carries off the silver and gold. Cupellation afterwards separates the lead, and the process of parting separates the silver, as we shall hereafter observe.

Gold exposed to the fire becomes red long before it melts. In a strong heat it appears of a brilliant sea green colour; but it does not melt till heated to whiteness, and crystallizes by slow cooling. The strongest heat of a furnace continued for an indefinite time, does not produce any change in this metal: Kunckel and Boyle made this experiment, by exposing gold for several months to the fire of a glass-house. This inalterability however is merely relative to the fires we are able to make with combustible substances; for it appears certain that a stronger heat, such as that of the sun concentrated by glass lenses, is capable of depriving it of its metallic properties. Homberg observed that this metal, when exposed to the focus of the lens of Tschirnhausen, fumed, was volatilized, and even vitrified. Macquer found, that gold exposed to the focus of the lens of M. Trudaine, melted and exhaled a fume which gilded silver, and was therefore gold in a volatile state; that the globule of melted gold was agitated with a rapid circular motion, and became coloured with a dull, and as it were, calciform pellicle; and lastly, that a violet vitrification was formed on

the middle of the globule. This vitrification gradually extended, and produced a kind of button, flatter or of a larger curvature than that of the globule, which stuck on the globule itself, as the transparent cornea appears on the sclerotica of the eye. This glass increased in size, while the gold itself continually diminished; the support always appeared tinged with a purple colour, apparently produced by the absorption of part of the glass.

Time did not permit Macquer to vitrify intirely a certain quantity of gold. This celebrated chemist observes, that it is a necessary condition, that the violet glass should be reduced with combustible matters, in order to justify the assertion, that it is the calx of that perfect metal, which would evidently appear to be the case, if it became revived into gold. However this may be, we think it may be considered as a true vitrified calx of gold, with so much the greater probability, as in many operations with this metal, presently to be described, the purple colour is constantly produced, and that many preparations of gold are employed to give that colour to enamel and porcelain. Gold is therefore calcinable like the other metals, and only requires, as likewise does silver, a stronger heat, and a longer time to unite with the base of air than other metallic substances. These circumstances, no doubt, bear

bear relation to its density, and its small tendency to unite with the oxygenous principle. Gold may be perfectly calcined by the action of a strong electric spark.

Gold is not changed by exposure to air; its surface becomes tarnished merely by the deposition of foreign bodies which continually float in the atmosphere. Water does not at all change it, though, according to the experiments of Lagaraye, it seems capable of dividing it nearly in the same manner as it does iron.

Gold does not combine with earths, or the salino-terrestrial substances in its metallic state; its calx makes a part of the composition of glasses, to which it gives a violet or purple colour.

Gold is not at all altered by the most concentrated vitriolic acid, even though heated.

The nitrous acid appears capable of dissolving a small portion of this metal, perhaps rather mechanically, than by a true combination. Brandt was one of the first chemists who affirmed, that the nitrous acid dissolves gold, and his assertion has been confirmed by Scheffer and Bergman; but it must be observed, that experiments made by the whole class of chemists of the academy of Paris, shew, that the nitrous acid only takes up a small portion of gold in peculiar circumstances,

circumstances, not mentioned by those chemists. Deyeux, member of the College of Pharmacy, has observed, that the nitrous acid dissolves gold only when it is smoking, and charged with nitrous gas; he thinks that the acid in this state is not pure, and affirms that it is loaded with gas, and by that means converted into a kind of aqua regia.

The muriatic acid alone, and in a state of purity, does not sensibly act on gold. Messrs. Scheele and Bergman have discovered, that this acid, when dephlogisticated or aerated, dissolves gold absolutely in the same manner as aqua regia, and forms with this metal the same salt which is usually obtained with the mixed acid or aqua regia. The solution appears to take place in consequence of the excess of oxygenous principle united to the muriatic acid; it is made without sensible effervescence, a circumstance common to all metallic solutions in the aerated muriatic acid.

Aqua regia has been considered as the true solvent of gold; it does not however dissolve it better than the aerated muriatic acid. Without repeating in this place, what we have elsewhere said respecting the nature, properties, and differences of this mixed acid, according to the quantity of the two acids combined together in its formation, we shall only attend to its action on gold.

gold. As soon as the aqua regia comes in contact with the metal, it attacks it with an effervescence which is so much the stronger, as the acid is more concentrated, the temperature higher, and the gold more minutely divided. The operation may be hastened by a gentle heat, or at least its commencement may be forwarded; the bubbles succeed each other without intermission, till a portion of the metal is dissolved, after which this appearance gradually ceases, and cannot be renewed but by agitation or heat; nitrous gas is disengaged during this solution. The aqua regia, when saturated with as much gold as it is capable of taking up, is of a yellow colour, more or less deep, considerably caustic, corrodes animal matters, and tinges them of a deep purple colour. By cautious evaporation it affords crystals of a beautiful gold colour, resembling topazes, and appearing to consist of truncated octahedrons, and sometimes tetrahedral prisms. This crystallization is not easily effected. M. Monnet thinks that it arises from the neutral salt formed in the aqua regia, and affirms that it is necessary, in order to obtain these crystals, that an aqua regia made with nitrous acid and sal-ammoniac, or marine salt, should be employed: the mixed acid then contains either nitre of soda, or ammoniacal nitre. According to this chemist, either of these neutral salts
causes

causes the crystallization of gold: nevertheless it appears, that a solution of gold, in an aqua regia made with the pure muriatic and nitrous acid, is capable of affording crystals; and Bergman considers this salt as a true muriate of gold: if the crystals be heated, they melt and assume a red colour. This salt strongly attracts the moisture of the air. When a solution of gold is distilled, a beautiful red liquor is obtained, which is found to consist of the muriatic acid, charged with a small portion of gold. The alchemists, whose labours with gold were very great, gave the name of the red lion to this liquor. Some crystals of gold of a reddish yellow colour, are likewise sublimed in this process; but the greatest part of the metal remains at the bottom of the retort, and requires only to be fused, in order to regain all its properties.

The solution of gold is decomposed by a great number of intermediums. Lime and magnesia precipitate gold in the form of a yellowish powder; fixed alkalies exhibit the same phenomenon; but it must be observed, that the precipitate is afforded very slowly, and that the solution assumes a reddish colour, if more alkali be added than is necessary; because the excess of this salt redissolves the precipitated gold. The precipitate of gold may be reduced by heat alone, in closed vessels, this calx readily suffering

fering the oxygenous principle to become disengaged in the form of vital air. It is nevertheless capable of being fused with vitreous matters, and communicating a purple colour to them; for the precipitate of gold formed by the mixture of a solution of gold, and the liquor of flints is used in enamels and porcelain.

Gold precipitated by fixed alkalies, has likewise a property very different from that of gold in its metallic state; it is soluble in the pure vitriolic nitrous and muriatic acids; all these acids heated on the yellowish precipitate of gold, readily dissolve it, but do not become sufficiently saturated to afford crystals. When the solutions are evaporated, the gold is readily precipitated, as likewise happens by mere rest. M. Monnet has observed, concerning the precipitation of the solution of gold by nut-galls,* a fact

* As we have only spoken of the precipitation of iron by nut-galls, it will be proper in this place to give a short account of the phenomena this astringent substance presents with most other metallic solutions.

Nut-gall precipitates the solution of cobalt of a light blue colour; that of zinc of a cinereous green; of copper, green which becomes grey and reddish; of silver, first reddish stræ, which soon takes the colour of burnt coffee; that of gold purple. These facts have been observed and described by M. Monnet, who likewise found that the precipitates are soluble in acids, and that alkalies unite to the last-mentioned solutions, without occasioning any precipitate.

To

fact which ought not to be overlooked, viz. that the reddish precipitate it affords, is readily soluble in the nitrous acid, to which it gives a beautiful blue colour.

Volatile alkali precipitates the solution of gold in much greater abundance. This precipitate, which is of a brown yellow, and sometimes of an orange colour, has the property of detonating with a considerable noise when gently heated: it is called fulminating gold. The volatile alkali is absolutely necessary in the production of fulminating gold; this preparation may be formed either by precipitating a solution of gold in an aqua regia, made with sal-ammoniac, by the addition of fixed alkali, or by precipitating a solution of gold, made with aqua regia, composed of pure nitrous and muriatic acid: by the addition of volatile alkali the fulminating gold always weighs one fourth more than the gold dissolved in aqua regia. The terrible effects of fulminating gold, render it necessary to act with great

To these the academicians of Dijon have added the following facts: solution of arsenic is not altered by nut-gall; that of bismuth, affords a greenish precipitate; of nickel, a white precipitate; of antimony, a blackish grey; of lead, a slate coloured precipitate, whose surface is covered with a mixture of green and red pellicles; lastly, that of tin becomes of a dirty grey by the mixture of nut-gall, and affords an abundant precipitate, of a mucilaginous appearance.

Note of the Author.

caution

caution in the management of this substance: it must be carefully dried in the open air, without being brought near the fire, as a strong heat is not necessary to produce the fulmination, and friction alone is sufficient for this purpose: the vessels which contain it ought not to be closed with glass stoppers, but with cork; the most dreadful accidents have shewn that glass stoppers, by the friction they produce in the necks of the vessels, expose the operator to great danger, from the fulmination of such particles of the gold as may remain between the stopper and the neck. A terrible accident happened in the laboratory of M. Baumé, which is related in his chemistry.

The opinions of chemists have been various respecting the cause of the detonation of fulminating gold. Baumé supposed that a nitrous sulphur, to which he attributes the fulminating property, is formed in this experiment; but Bergman has shewn that this theory is not admissible, since he made fulminating gold without the nitrous acid, by dissolving a vitriolic precipitate of gold in the acid, and precipitating it again by the volatile alkali. Neither does the fulmination of gold depend on ammoniacal nitre, since this salt would certainly be washed off by the addition of much water; and it is not found that fulminating gold loses its property by such treatment. An attentive examination

examination of the fulmination of gold shews, that it takes fire in the instant that it explodes; if it be heated very gently, brilliant sparkles, similar to those of electricity, are seen to escape before its explosion. The discharge of an electric jar produces a detonation, but a simple electric spark does not. Lastly, after the fulmination, the gold is found in its metallic state. The fulmination of gold therefore appears to be produced by a combustible matter; and as alkaline gas is necessary for the production of this compound, it is at present acknowledged that the explosion arises from the volatile alkali; this theory is founded on the following facts.

1. M. Berthollet obtained alkaline gas, by gently heating fulminating gold in copper tubes, one extremity of which was plunged, by means of a syphon, beneath the mercury of a pneumato-chemical apparatus; after this experiment the gold was deprived of its fulminating property, and reduced to calx.

2. By exposing fulminating gold to a degree of heat, not sufficient to cause it to fulminate, Bergman deprived it of that property by gradually volatilizing the alkaline gas.

3. When a few grains of fulminating gold are detonated in copper tubes, whose extremity is plunged beneath the mercury of

of the pneumato-chemical apparatus, mephitis and a few drops of water are obtained, and the gold is reduced. M. Berthollet, the inventor of this experiment, thinks that the volatile alkali is decomposed, that its inflammable gas, uniting with the oxygenous principle of the calx of gold, reduces the calx by forming water, and that the mephitis is set at liberty; the fulmination, therefore, depends on the combination of the inflammable gas and the disengagement of the mephitis.

4. Concentrated vitriolic acid, melted sulphur, fat oils, or ether, deprive gold of its fulminating property, by seizing the volatile alkali. A singular property of fulminating gold, which shews its powerful action is, that when it is exploded on a plate of metal, either lead, tin, or even copper, it makes a mark or perforation in it. Lastly, it does not appear capable of taking fire in very strong and well closed vessels, since it produced no explosion in an iron ball well closed and strongly heated. This phenomenon appears to depend on its being necessary that a space should be left for the disengagement of the mephitis. Bergman, who was not well acquainted with the nature of the gas disengaged during the fulmination of this precipitate, and who considered it as pure air, together with a small portion of volatile alkali, has

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given a similar explanation of the experiments made by the Royal Society of London.*

The solution of gold is precipitated by liver of sulphur, while the fixed alkali unites to the aqua regia; the sulphur which falls down combines with the gold, but this combination is by no means strong, for the sulphur may be driven off, and the perfect metal left pure by the application of heat. We must here observe, that gold precipitated from aqua regia by any intermedium whatsoever, is perfectly pure, even more so than gold purified by the process of parting; because it is separated from the silver it may contain in this last process, which may fall down in the form of lunar cornea, and takes place even during the solution of gold, as we have before remarked.

Gold has not the strongest affinity of any metal with aqua regia; almost all other metallic substances, on the contrary, separate it from its solvent: bismuth, zink, and mercury, precipitate gold; a plate of tin plunged in a solution of gold, separates the perfect metal in the form of a deep violet powder, called purple precipitate of Cassius. This precipitate, which is used in painting in enamel and on porcelain,

* See the valuable dissertation of this chemist on the fulminating calx of gold, vol. II. of his Chemical Essays. London, 1784.

is prepared by diluting a solution of tin in aqua regia, with a large quantity of distilled water, and pouring in a few drops of the solution of gold; when the solutions are well saturated, a red or crimson precipitate is immediately formed, which at the end of a few days becomes purple: this precipitate is light, and as it were mucilaginous; it is separated from the liquor by filtration, washed and afterwards dried. It consists of the calces of tin and gold, and its preparation is one of the most singular operations in chemistry, with respect to the variety and uncertainty it exhibits; sometimes the precipitate is of a beautiful red, sometimes its colour is a deep violet; and, what is still more astonishing, it frequently happens that the mixture of the two solutions causes no precipitate whatever. Macquer, who very carefully observed these varieties, finds that they depend almost always on the state of the solution of tin made use of; if the solution has been made too rapidly, the metal is too much calcined, and is contained in too small a quantity for the aqua regia of the solution of gold to act on it; for it is to the action of this last on the tin, that he attributes the formation of the purple precipitate of Cassius. In order to succeed in this operation, according to him, the solution of tin must be made very slowly, and in such a manner that it may contain the

greatest possible quantity of metal not too much calcined: on these principles he lays down the following processes for making purple precipitate. Pieces of tin are to be dissolved in aqua regia, made of two parts of spirit of nitre, and one of spirit of salt, diluted with an equal weight of distilled water; on the other hand, very pure gold must be dissolved by heat in an aqua regia, composed of three parts of spirit of nitre, and one part of spirit of salt; the solution of tin is to be diluted in 100 parts of distilled water, and divided into two portions; to the first of the two, an additional quantity of water is to be added, and each must be tried with a drop of the solution of gold; that which affords the most beautiful red colour must be noted, and the same management adopted with the others, after which the solution of gold must be poured in till it no longer occasions any precipitate.

Lead, iron, copper, and silver have likewise the property of separating gold from its solvent; lead and silver precipitate it of a deep and dirty purple; copper and iron separate it with its metallic brilliancy; the nitrous solution of silver, and that of martial vitriol, likewise occasion a red or brown precipitate from any solution of gold. The action of neutral salts on gold is not perceptible; it is only observed that borax, fused

fused with this metal, alters its colour, and renders it remarkably pale, whereas nitre or marine salt re-establish the colour. The solution of borax poured into the solution of gold, causes a precipitate of sedative salt, charged with particles of the metal.

Sulphur is incapable of uniting with gold, and is advantageously used to separate metals, with which gold may be alloyed, more especially silver: this alloy is melted in a crucible, and flowers of sulphur, or sulphur in powder, is thrown on its surface: the latter substance, melting and combining with the silver, floats above the gold in the form of a blackish scoria. It must be observed, that this operation, called dry parting, never separates the two metals accurately from each other, and that it is not used, excepting when the mass of silver does not contain a sufficient quantity of gold to repay the expence of the operation of parting by aqua fortis.

Liver of sulphur completely dissolves gold. Stahl even thinks that this process was used by Moses, to render the calf of gold adored by the Israelites soluble in water: to form this combination, a mixture of equal parts of sulphur and vegetable alkali must be quickly fused with one-eighth part of the whole weight of leaf gold; this matter being poured out and levigated on a stone, forms, with hot distilled water,

a yellowish green solution, containing an auriferous liver of sulphur; the metal may be precipitated by means of acids, and separated from the sulphur which falls down at the same time, by heating it in an open vessel.

Gold combines with most metallic substances, and exhibits many important phenomena in its combinations.

It unites with arsenic, and forms a brittle pale compound; the last portions of arsenic are very difficultly separated from this alloy by the action of heat; the gold seems to communicate fixity to it.

The alloy of cobalt with gold has not been examined.

It unites with bismuth, which renders it brittle, as do likewise nickel and the regulus of antimony; as these semi-metals are very calcinable, and, for the most part, fusible, they are easily separated from gold by the combined action of fire and air.

Crude antimony has been greatly extolled by the alchemists for the purification of gold; when this substance is melted with gold, alloyed with other metallic substances, as copper, iron, or silver, the sulphur of the antimony unites to the alloy, and separates them from the gold, which is found at the bottom of the vessel; this gold is contaminated with regulus of antimony, and must be purified by a white heat;
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the regulus of antimony, by this treatment, is volatilized, but the last portions require a very strong heat to drive them off. It is likewise observed that the semi-metal carries up certain portions of gold in its volatilization. This process, so celebrated by the alchemists, has not, therefore, any advantage over that in which sulphur is employed alone.

Gold readily unites with zink; the product is a mixed metal, more brittle and white in proportion as the quantity of semi-metal is greater; this alloy, made with equal parts of each metal, is of a very fine grain, and takes so beautiful a polish, that it has been recommended by Hellot to make mirrors of telescopes, not being subject to tarnish. When the zink is separated from the gold by calcination, its flowers are reddish, and carry up a small quantity of gold with them, as Stahl has observed.

Gold has a stronger affinity with mercury than with other metallic substances, and is capable of decomposing their amalgams; it unites with mercury in every proportion, and forms an amalgam which is more solid, and of a darker colour, in proportion as the quantity of gold is greater; this amalgam liquifies by heat, and crystallizes by cooling, as do most compounds of this nature; it is not well known what regular form it takes. M. Sage affirms, that the cry-

stals resemble plumose silver, and, by the magnifier, appear to be quadrangular prisms. He likewise asserts, that the mercury acquires fixity in this combination. This amalgam is employed in water-gilding.

Though gold is not capable of calcination by the action of the fire of our furnaces with access of air, it nevertheless becomes calcined when heated together with mercury: if mercury with one forty-eighth of its weight of gold, be heated in a flat-bottomed matrafs, whose neck is drawn out into a capillary tube, in the same manner as is done in the preparation of the calx of mercury, called precipitate per se, the two metallic substances become calcined at the same time, and are converted into a deep red powder. This compound calx, according to Baumé, is obtained in much less time than that of mercury alone. We here see a metal, which, though very difficult to calcine alone, assists and facilitates the calcination of another metallic matter, which is likewise very difficultly calcined.

Gold is easily alloyed with tin and lead; these two metals deprive it of all its ductility; its alloy with iron is very hard, and may be used to form cutting instruments, much superior to those made with pure steel: this mixture is grey, and attracted by the magnet. Lewis proposes gold as a very

very proper and firm solder for small pieces of steel.

Gold combines with copper, which gives it a red colour, and greater firmness, at the same time that it renders it more fusible; this alloy is mixed in different proportions for money, plate, and toys. Lastly, gold is alloyed with silver, which deprives it of its colour, and renders it very pale: this alloy is not, however, made without a certain degree of difficulty on account of the different specific gravities of these two metals, as Homberg observes, who saw them separate during their fusion. The alloy of gold with silver forms the green gold of the jewellers and gold-beaters.

As gold is of the most extensive use, and by the convention of mankind, is become, together with silver, the price of all the other productions of nature and of art; it is of importance to ascertain the degree of purity of this precious metal, in order to prevent the deceptions which covetousness might produce, and to cause the value of all the masses or pieces of gold, dispersed in commerce, to be the same, equal weights being supposed. Severe laws, founded in justice, have therefore been made, establishing the quantity of alloy necessary to be used, in order to give the due degree of hardness and rigidity to gold intended to form utensils, in which these properties are necessary. Chemistry
affords

affords methods of ascertaining the quantity of imperfect metal mixed with gold : the operation by which this knowledge is obtained, is called the assay of gold. Twenty-four grains of the gold intended to be assayed, is cuppelled with forty-eight grains of silver and four drams of pure lead ; the latter, in its vitrification, carries along with it the imperfect metals, such as copper, &c. and the gold remains combined with the silver : after the cuppellation is finished, these two metals are separated by an operation, called parting ; the parting of gold and silver consists in the separating of the two metals by a solvent, which acts on silver without affecting gold : aqua fortis is commonly used. Silver is added to the gold, because experience has shewn, that it is necessary the gold should be mixed with at least double its weight of silver, in order that the nitrous acid may perfectly dissolve the latter metal. As three parts of silver are usually added to one of gold, this process is called quartation ; the gold being one-fourth of the weight of the alloy.

The metallic button being hammered flat, and care being taken to heat it from time to time, lest it should become hard and break in pieces, and some part fly away, and be lost ; it is then rolled up in a spiral form, and put into a small matrafs, with five or six drams of precipitated aqua fortis, in which
there

there is no mixture of the muriatic acid, and which has been previously diluted with half its weight of water: a gentle heat is applied till the effervescence has taken place; the silver becomes dissolved, and the metallic coil assumes a brown colour. When the action of the acid has ceased, it is decanted off; the spiral piece of metal which is now become very thin and porous, is washed with water, and put into a crucible, together with the water; the water is then decanted off, the crucible made red hot, and the gold is found pure with all its metallic properties: by the weight of the gold, the quantity of alloy it originally contained is known. To ascertain with precision the quantity of imperfect metal which the gold may contain, a given mass of gold is supposed to contain twentyfour parts, called carats; and, for great exactness, each carrat is divided into thirty-two parts, called thirty seconds of a carrat: if the gold after the assay has lost one grain out of twenty-four, it is gold of twenty-three carrats; if it has lost one grain and a half, it is gold of twenty carats sixteen thirty-seconds, and so forth. The weight used in the assay of gold, is called the assay weight, and usually consists of twenty-four grains; it is divided into twenty-four carats, which are likewise subdivided into thirty-two parts: an assay weight, which weighs twelve grains, is likewise used, but
divided

divided into twenty-four carats, and the carat into thirty-two thirty seconds.

There are two important observations necessary to be made, respecting the operation of parting.

1. Some chemists have thought that the nitrous acid dissolves a small quantity of gold with the silver. M. Baumé has observed, pages 117 and 118, of the third volume of his chemistry, that the silver obtained in the operation of parting, contains a notable quantity of gold. Out of two pounds of fine grain silver, used by this chemist, to make lapis infernalis; he affirms, that he has usually separated near half a drachm of gold in the form of a black powder; however, when the parting is made with an acid not too much concentrated, and the solution is not carried too far, the gold remains pure and untouched, and the silver contains no portion of that metal. The gentlemen of the chemical class of the academy, were directed by administration, to examine whether, in the process of parting, the nitrous acid dissolves gold; they made a great number of experiments, from which they concluded, that in the operation of parting, according to the received rules and usage, there can never be the smallest loss on the gold, and that this operation may be considered as perfect. This decision, extracted from the report published by the academy, is well calculated

calculated for the information of the public, and the establishment of commercial confidence respecting this subject.

2. Many docimastic philosophers, and amongst others Schindler and Schlutter, have thought that the coil of gold, after parting, retained a small quantity of silver; to this portion they gave the name of surcharge, or interhalt. Messrs. Hellot, Macquer, and Tillet, who were commissioned to examine the operation of the assayers of money, have proved, that it does not contain silver; yet M. Sage affirms in his work, intituled, *L'Art d'essayer l'or et l'argent*, page 64, that this gold always retains a small proportion of silver, and that it may be exhibited by dissolving the metal in twelve parts of aqua regia, the cold solution depositing, at the end of a certain time, and often, even twelve hours after it has been made, a small quantity of luna cornea, in the form of a white powder.

Gold is applied to a great number of uses; its scarcity and price prevent its being made into utensils, or vessels; but as its brilliancy and colour are very agreeable, methods have been found of applying it to the surface of a great number of bodies, which it at the same time defends from the impressions of the air.

This art, in general called gilding, is performed in a variety of methods. Leaves of gold

gold are often applied on wood by means of some glutinous substance. A powder of gold is prepared by triturating the clippings of gold leaf with honey, washing the paste with water, and drying the particles of gold, which precipitate. Shell gold is the last mentioned preparation, mixed with a mucilaginous water, or solution of gum. The name of gold in rags is given to the following preparation: rags are steeped in a solution of gold, and afterwards dried and burned for use; a wet cork is dipped in these ashes, and rubbed on silver, upon which the minutely divided gold easily applies itself. We have already spoken of water-gilding; this is done by previously cleaning a piece of copper, intended to be gilt, with sand, and weak aqua fortis, called aqua secunda, after which the piece is plunged in a diluted solution of mercury; the mercury which precipitates, causes the amalgam of gold to adhere; which is spread on the piece, after having washed it with water to carry off the acid: when the amalgam is uniformly spread, the piece is heated on charcoal, to volatilize the mercury, and the work is finished by covering it with gilder's wax, composed of red bole, verdigrise, alum or martial vitriol, incorporated with yellow wax, and heated once more to burn off the wax.

The other uses of gold, for toys, laces, &c. are sufficiently known without enumeration.

ration. As to the medicinal virtues attributed to gold, it is admitted by all physicians of reputation, that they are imaginary, and that the effects of the different kinds of potable gold proposed by the alchemists, arise from the substances in which the metal has been mixed or dissolved.

C H A P. XXI.

Concerning Platina.

PLATINA, which has not been known as a peculiar metal for more than fourteen years, has been hitherto found only in the gold mines of America, more especially in those of Santa Fé, near Carthagena, and in the Bailiwick of Choco in Peru. The Spaniards give it this name from the word plata, which signifies silver in their language, by way of comparison to that metal, whose colour it imitates. The name of white gold however appears to agree better with its properties than that of little silver, because it in fact resembles gold much more than silver in most of its properties. Some toys made of platina were in existence before the time we have cited; but as this metal cannot be melted and wrought alone, it is probable that the snuff boxes, heads of canes,

canes, and other utensils of this kind, which were sold under the name of platina, were alloys of this metal with certain metallic substances, which might give it fusibility, as we shall see in the history of its alloys.

The platina, in mineralogical collections, has the form of small grains, its plates of a blueish black, whose colour is intermediate between those of silver and iron. These grains are mixed with many foreign substances; they contain small particles of gold, blackish ferruginous sandy grains which by the magnifier appear scorified, and certain particles of mercury; the mercury is separated from this mixture by heating; washing carries off the sand, and grains of iron, which may likewise be separated by the magnet; after which the particles of gold and grains of platina only remain, which are easily separated according to Margraaf. If the grains of platina be examined by the magnifier, some appear regular, others round and flat, like a kind of button. When beat on the anvil, most of them are flattened, and appear ductile; some break into several pieces; the latter examined more narrowly, appear to be hollow, and particles of iron and a white powder has been found within them. The property of being attracted by the magnet, which these grains possess, though accurately separated from the ferruginous sand they contain, must doubtless be attributed

to

to a portion of iron contained within them.

The hardness of this metal nearly approaches to that of iron; the specific gravity of platina, mixed with all the foreign matters we have spoken of, nearly approaches to that of gold; it loses in water between one sixteenth and one eighteenth of its weight. Messrs. de Buffon and Tillet compared together an equal volume of platina, and of gold reduced into particles similar to those of the platina, and found that the specific gravity of the former was about one twelfth less than the gold; when purified by fusion, it approaches to the specific gravity of gold.

It is not probable that platina exists in its ores in the same form as it comes to us, but that its granular or plated figure, is produced by the motion of the waters by which it is carried from the mountains to the plains. It has been sometimes found in masses of considerable magnitude; the society of Biscay possess one of the size of a pigeon's egg. As it is found in the neighbourhood of gold mines, it is always mixed with a quantity of this metal. The mercury it contains is part of that used in extracting the gold. Though toys made of platina have been long sold, this metal was not distinguished as a peculiar substance till lately: the workmen paid no particular at-

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tention to it, and appear to have set no value on it, because of its dull aspect, and the difficulty of treating it. The first person who paid any particular attention to platina, was a Spanish mathematician, Don Antonio Ulloa, who accompanied the French Academicians in the celebrated expedition to Peru, for determining the figure of the earth. This philosopher gives a cursory account of it in the relation of his voyage, published at Madrid in the year 1748. Charles Wood, an English metallurgist, brought a quantity of this metal from Jamaica, in the year 1741, which he afterwards examined, and gave an account of his experiments in the Philosophical Transactions for the years 1749 and 1750: at this æra, the greatest chemists in Europe appeared emulous in their inquiries respecting this new metal, which promised, by its singular properties, such considerable advantages. Scheffer, a Swedish chemist, published his experiments on platina in the Memoirs of the Academy of Stockholm, in the year 1752. Lewis, an English chemist, made a connected and almost complete series of experiments on this metal, which may be found in the Philosophical Transactions for the year 1754. Margraaf has inserted in the Memoirs of the Academy of Berlin for 1757, an account of his experiments on this new metal. Most of these Memoirs were collected by Mr. Morin, in a work intituled *La platine, L'or blanc, ou le huitième*

huitième métal : Paris, 1758. At the same time Messrs. Macquer and Baumé made, in conjunction, a great number of important experiments on platina, which were published in the Memoirs of the Academy for the year 1758. M. de Buffon has given an account in the first volume of the supplement to his Natural History, of a series of inquiries respecting platina made by himself, M. de Morveau, and the Count de Milly. The Baron Sickengen has likewise made a series of experiments on this metal; his work has not yet been published, but Macquer has given an extract of it in his Dictionary of Chemistry. M. de L'Isle has communicated to the academy, certain experiments made by himself on platina. The scarcity of this metal, and the difficulties attending the experiments made on it, stopped for a time the progress of inquiries, but within the last few years they have been resumed with new spirit. Bergman, Achard, and de Morveau, have exerted themselves in the examination of the properties of this metal.

Platina purified and separated by washing, trituration, and by the muriatic acid, from the foreign bodies it may contain, and afterwards exposed to the most violent heat of a furnace, is not altered, but its parts slightly adhere together. All the chemists who have made experiments on this metal, agree in this respect. Messrs. Macquer and Baumé kept it for several days exposed to

the continual fire of a glass-house, without any other alteration, than that its grains were slightly adherent to each other; but this agglutination was so slight, that they separated even by touching. They observed, that in these experiments the colour of the platina became brilliant by a white heat; that it acquired a dull and greyish colour after it had been heated a long time; and lastly, that its weight was constantly increased as Margraaf had ascertained, which could only arise from calcination. These chemists exposed platina to the focus of a large burning mirror; it first smoked, then emitted very lively sparks, and lastly, those portions which were exposed to the centre of the focus, melted in the space of a minute. The melted portions were of a white brilliant colour, in the form of a button; they could be cut into pieces with a knife; one of these masses was flattened on the anvil, and converted into a thin plate, without cracking or breaking, but it became hard under the hammer. This valuable experiment shews, that platina is fusible by a fire of the utmost violence, that it is as malleable as gold and silver, and that it is scarcely alterable by the action of fire; for in all these experiments, most of which were made in the open air, the platina exhibited no appearance of calcination. M. de Morveau has likewise succeeded in melting platina in the wind furnace described by Mr. Macquer,

quer, by means of his own reducing flux, composed of eight parts of pounded glass, one part of calcined borax, and half a part of charcoal in powder. Small portions alone, and without addition, are now very easily melted, by heating them on a lighted charcoal, with a stream of vital air; but these small ductile globules cannot be applied to any use, on account of their inconsiderable size.

Platina, when exposed to air, is not at all changed; it is not however known what alteration it may be susceptible of, if kept red hot for a long time with contact of air: perhaps it might be calcined, as Junker affirms gold and silver are, when treated in the same manner.

This metal is not altered by water, earth, the metals, the salino-terrestrial substances, or by alkalies. The most concentrated vitriolic, nitrous or muriatic acids do not act on platina, even when boiling; neither is distillation, which is known to be so efficacious in promoting the action of acids on metallic substances, of any advantage in the present case. The vitriolic acid simply tarnishes the grains of platina, according to Lewis and Baumé; the nitrous acid, on the contrary, renders them brittle. Margraaf affirms, that towards the end of the distillation of this acid from platina, he obtained a small quantity of arsenic, a phenomenon not observed by other chemists. The muriatic acid produced

no change whatsoever in grains of platina. Margraaf likewise obtained from this acid, distilled from the metal, a white sublimate, which appeared to him to be arsenic, and a reddish sublimate, whose properties he could not examine on account of its being in so small a quantity. All these appear, however, to be foreign to the platina itself: this metal therefore resembles gold by the slight action of the simple acids upon it; but the analogy is still more evident by its solubility in the aerated muriatic acid, and in aqua regia.

The first of these acids dissolves platina with facility, and without the assistance of a strong heat; seventy or eighty degrees of heat in the atmosphere being sufficient to facilitate this solution, which takes place without any sensible effervescence, and in other respects does not differ from the following.

The aqua regia best adapted to dissolve platina, is composed of equal parts of the muriatic and nitrous acids. To effect this solution, which in general is less easily performed than that of gold, one ounce of platina must be put into a retort, on which a pound of aqua regia, in the proportions here mentioned must be poured; the retort is then to be placed on a sand bath, with a receiver applied as soon as the acid is hot; a few bubbles of nitrous gas are extricated, and the action of the aqua regia proceeds without violence or rapidity: the colour of the fluid becomes

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at first yellow, afterwards orange, and at last of a very deep brown. When the solution is finished, reddish and black particles of sand are found at the bottom of the retort, from which the saturated liquor is to be separated by decantation: small irregular crystals of a dusky colour are gradually deposited, which consist of a combination of the acid and platina. The solution of platina is of a deeper colour than that of any other metal. Though it appears of a dark brown, yet, if it be diluted with water, it assumes first an orange colour, which soon becomes yellow, and resembles the solution of gold: it tinges animal matters of a blackish brown, not at all inclining to purple. M. Baumé affirms, that platina fused in the focus of a burning mirror, and dissolved in aqua regia, does not assume a brown colour, like that of platina in grains, but that the solution is of a deep orange yellow colour.

Macquer affirms, that by evaporating and cooling the solution of platina, much larger and more regular crystals are obtained, than those spontaneously deposited by the saturated fluid. Lewis having left this solution to evaporate in the open air, obtained crystals of a deep red, of a moderate size, irregularly formed, and resembling the flowers of benzoin, though thicker: Bergman describes it as being of an octahedral form. This salt is sharp, but scarcely caustic; it melts in

the fire, the acid being dissipated, and a residue is left in the form of an obscure grey calx. Concentrated vitriolic acid occasions a precipitate of a deep colour, which, doubtless, is a vitriol of platina; the muriatic acid, in a certain time, produces a yellowish deposition.

Alkalies and the salino-terrestrial substances decompose the solution of platina, and precipitate the metal in the form of calx: the cretaceous vegetable alkali produces an orange coloured precipitate, in the solution of platina, which is not a pure calx. Messrs. Macquer and Baumé have observed that its colour is owing to a certain quantity of acid it contains. It must therefore be considered as a mixture of a portion of the calx of platina, with muriate of pot-ash, or as a kind of triple salt. This opinion is proved by washing the precipitate with hot water; for the fluid then becomes coloured by dissolving the salt of platina, and the residue, which is a pure calx of the metal, is grey. Fixed alkali, boiled on this precipitate, quickly deprives it of its colour, and leaves a calx of platina, which is of a pearl colour, according to the experiments of M. Baumé: this chemist was convinced that the precipitate of platina is soluble in the alkali, because a solution of the metal, dropped into an hot solution of cretaceous vegetable alkali, afforded no precipitate. For this reason, it is
that

that the solution precipitated by fixed alkali always retains a deep colour, and affords platina by evaporating it to dryness. Margraaf has discovered that soda does not precipitate the solution of platina, but Bergman has observed, that on the addition of a considerable quantity of that alkali a precipitate is readily afforded.

Alkalies saturated with the colouring matter of Prussian blue, form an abundant blue precipitate, which, according to M. Baumé, arises from the iron contained in the alkali; since Prussian blue deprived of the iron it contains, by the process directed by that chemist, does not afford more than a few particles of blue, with the solution of platina, which arise from the small portion of iron always contained in that metal. Bergman affirms that the Prussian lixivium, well saturated and very pure, does not precipitate the solution of platina; and that this metal is the only one not precipitated by the Prussian lixivium; he, therefore, proposes that lixivium to separate from the iron which it always contains.

The caustic volatile alkali precipitates platina of an orange yellow: this precipitate is almost intirely saline; water dissolving the greatest part, and becoming coloured like a solution of gold. After the action of water on this precipitate, a blackish substance, which appears to be ferruginous, remains. The precipitate of platina by volatile alkali,
differs

differs from that of gold in its not possessing the fulminating property of the latter.

Nut-galls precipitate the solution of platina of a deep green colour, which gradually becomes lighter by standing.

All the precipitates obtained from the solution of platina by the addition of alkaline substances, are not capable of being vitrified, or of colouring glass. In the trials of Lewis and Baumé, on this subject, the platina was constantly reduced in grains, in ramifications, or a kind of checquer work. A sort of button of platina may be obtained by exposing these precipitates to a strong heat, with certain reducing fluxes, as borax, cream of tartar, glass, &c. Messrs. Macquer and Baumé succeeded in this manner by a forge fire, urged by two pair of strong bellows, to melt in thirty-five minutes, a precipitate of platina mixed with fluxing substances: they obtained, beneath a hard blackish glass resembling that of bottles, a button of platina, which appeared to have been well fused: this button was not ductile, but broke into two pieces, and appeared to be hollow; its fracture was grained, and its hardness nearly equal to that of forged iron, as it made deep traces in gold, copper, and even in iron. Though we have affirmed that the precipitates of platina do not appear to be vitrifiable or capable of tinging glass, yet M. Baumé has succeeded in melting them into a vitriform substance by two different

ferent processes. The precipitate of platina, mixed with calcined borax, and a very fusible white glass, was exposed for thirty-six hours in the hottest part of a potter's furnace, and afforded a greenish glass, inclining to yellow, without globules of reduced metal. This glass treated a second time with cream of tartar, gypsum, and vegetable alkali, was completely melted, and exhibited globules of platina dispersed through their substance. M. Baumé separated them by washing, and found them ductile. The same chemist afterwards, together with M. Macquer, exposed precipitate of platina to the same burning mirror with which they had fused the metal: the precipitate exhaled a very thick and luminous fume, with a strong smell of aqua regia; it lost its red colour, resumed that of platina, and melted into a perfect brilliant button, which was found to be an opaque vitreous substance, of an hyacinthine colour at its surface, and blackish within, and may be considered as a true glass of platina. It may however be observed, that the saline matters with which it was impregnated, contributed doubtless to its vitrification.

The precipitate of platina does not appear to be soluble in simple acids, but it dissolves very well in aqua regia, to which it gives an orange colour, not at all resembling the brown colour exhibited by the platina in grains.

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The solution of platina is not precipitated by the alkaline or perfect neutral salts; but sal-ammoniac precipitates it abundantly. The rationale of this experiment is not well decided. The orange-coloured precipitate obtained, by pouring a solution of sal-ammoniac into a solution of platina, appears to be a saline substance, intirely soluble in water; this precipitate has a valuable property, discovered by M. de L'Isle, viz. that it is fusible without addition, in a good furnace or common forge heat. The platina melted by this process is a brilliant dense and close grained button; but it is not malleable, unless it has been exposed to a very strong heat. Macquer thinks that this fusion, like that of the grains of platina exposed alone to the action of a violent fire, consists only in the agglutination of the softened particles, which being exceedingly more divided and minute than the grains of platina, adhere to and touch each other in a greater number of points than the grains; and in that manner render the texture of the metal much more close, though no true fusion may have taken place. It seems, however, that if platina in grains be capable of fusion by the burning glass, and of becoming considerably ductile, the precipitate of this metal made by sal-ammoniac, may likewise be fused on account of its extreme division; and that its not being as ductile as the

the button of platina fused by the solar heat, may perhaps depend on its still retaining a part of the matter it carried down with it in its precipitation, of which it may be possible to deprive it by fire.

Margraaf dissolved platina in an aqua regia composed of sixteen parts of nitrous acid, and one of sal-ammoniac; by distilling this solution to dryness, and heating the bottom of the retort till it was red, a salt of a deep red colour was sublimed, and the residue was in the form of a reddish powder. It is not known whether the solution of platina in simple aqua regia, made with the nitrous and marine acids, will afford a sublimate of the same kind by distillation.

Messrs. Margraaf, Baumé, and Lewis, mixed the solution of platina with solutions of all the other metallic substances; the result of their experiments was, that almost all the metals precipitate platina in the form of a brick-dust-coloured powder, and that none of these precipitates possess the metallic properties, as happens with most of the other metals. This exhibits another analogy between gold and platina, though the latter does not afford a purple precipitate with tin, but a brown precipitate, inclining to red. With regard to the effect of the different metallic solutions on that of platina, it need only be observed, that the solutions of
bismuth

bismuth and lead by the nitrous acid, of iron and copper by different acids, and of gold by aqua regia, do not produce any precipitate in that of platina, according to Margraaf; but that on the contrary, those of the arsenical neutral salt, of zink and of silver, by the nitrous acid, precipitate it; the first in the form of a crystallized substance, in small quantity, and of a beautiful gold colour; the second in a red orange coloured matter, and the third in a yellow matter. These different precipitates have not yet been well examined; and the decomposition by which they are occasioned is unknown.

Most of the neutral salts have no action on platina. Margraaf heated platina by a strong fire, with vitriolated tartar and Glauber's salt; these salts melted, and the platina remained in grains without alteration: it only communicated a slight reddish colour to the saline substances, doubtless on account of the iron communicated by the metal to them.

Nitre produces a singular alteration in platina, according to the experiments of Lewis and Margraaf. Though no detonation is produced when a mixture of both substances is thrown into a red hot crucible; yet, by a strong heat long continued, such as Lewis applied for three successive days and nights to a mixture of one part of platina and two of nitre, the metal becomes of a rusty colour.

colour. If the mixture be boiled in water, the fluid dissolves the alkali, which takes up the brownish powder, and the platina separated from the liquid is found diminished more than one-third of its weight. The brown powder taken up by the alkali may be separated by filtration. It appears to be a kind of calx of platina, mixed with a small quantity of saffron of Mars. Lewis converted this calx to a whitish grey colour, by distilling it a great number of times with sal ammoniac. Margraaf, who repeated this experiment, adds two important facts; the first is that platina combined with the alkali of nitre, and diluted in a certain quantity of water, forms a jelly; and the other, that by calcining the portion of metal separated from the jelly, diluted with water and filtrated, it becomes of a black pitchy colour. This experiment certainly shews a great alteration of the platina, and requires to be continued, in order to decide whether by virtue of repeated calcinations with nitre it be possible to reduce the whole of the metal into a brown powder, and especially to determine the state of the platina thus calcined.

Marine salt, febrifuge salt, borax, and the earthy salts, produce no change in platina, nor facilitate its fusion; sal ammoniac, distilled with this metal, affords a small quantity of martial flowers by virtue of

of the iron it contains. Chemists are not agreed respecting the mutual action of arsenic and platina. Scheffer first asserted, that arsenic causes this metal to enter into fusion; but the experiment succeeded but imperfectly in the hands of Lewis, and not at all with Margraaf, Macquer, and Baumé. This experiment has been since repeated, and it appears that platina is in fact very fusible with arsenic, but that it remains brittle. In proportion as the arsenic is driven off by a continuance of heat, it becomes more ductile, and by this process it is, that M. Achard and M. de Morveau succeeded in making crucibles of platina, by melting it a second time in moulds. No one has attempted to combine cobalt, nickel, or manganese with platina.

This perfect metal unites very well with bismuth, which renders it so much the more fusible, as the quantity of the latter is greater; the alloy is brittle, and becomes yellow, purple, and blackish in the air. This mixed metal cannot be cuppelled without the greatest difficulty, and never forms a mass of any considerable ductility.

Platina fuses readily with regulus of antimony, and produces a brittle metal of a plated texture, from which the regulus may be separated by the action of fire, though not so completely, but that the platina always retains a sufficient quantity to render it

it defective in weight and ductility. Zink renders platina very fusible, and combines readily with it: this alloy is brittle, and difficult to file; its colour is blueish. When the platina is most abundant, these two metallic substances are separated by the action of fire, which volatilizes the zink, though the platina always retains a small portion.

Platina does not unite with mercury, though triturated for several hours with that metallic fluid. It is likewise known, that platina resists the mercury used in America to separate the gold. Many intermediums, such as water, used by Lewis and Beaumé, and aqua regia by Scheffer, have not been found to facilitate the union of these two metals. In this respect platina appears to resemble iron, to whose colour and hardness it likewise in some respects approaches.

Platina mixes very easily with tin, and forms a very fusible and fluid alloy. It is brittle, so as even to break by a fall when the two metals are united in equal portions. When the tin is in the proportion of twelve or more to one of platina, the mixture is considerably ductile, but its grain is coarse, and it becomes yellow in the air. Platina remarkably diminishes the ductility of tin, and the alloy does not promise to be of any use; yet when it is well polished, it may remain long exposed to the air without alteration. It seems that Lewis, to whom we are in-

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debted for most of the knowledge we possess respecting the alloys of platina, succeeded in calcining this metal, and dissolving it in the muriatic acid by means of tin.

Lead and platina unite very well by fusion; but they require a stronger heat than the last mentioned alloy. Platina deprives lead of its ductility; the combination of these two metals is of a purplish colour, and brittle, according to the proportions of platina, striated and granulated in its fracture, and quickly changes by exposure to air. Cupellation with lead, was one of the first and most important experiments attempted to be made with platina; because this operation was expected to deprive it of the foreign metallic substances it might contain. Lewis, and several other chemists, have in vain attempted to cuppel platina in the ordinary cuppelling furnaces, though they applied a most violent heat. The vitrification and absorption of the lead takes place as usual at the commencement of the process, on account of the excess of that metal; but the platina soon becomes fixed, and the operation is at an end. The metal remains united with a portion of the lead, and is not at all ductile. Messrs. Macquer and Baumé, succeeded in the perfect cupellation of platina, by exposing an ounce of the metal, and two ounces of lead, in the hottest part of the porcelain furnace at Seves. The wood fire
lasts

lasts for fifty hours successively; at the end of this time the platina was found flattened on the cuppel; its upper surface was dull and rough, and easily separated; its under surface was brilliant, and, what is the most valuable, it was easily extended under the hammer. These chemists were convinced, by every possible method, that the platina did not contain lead, but was very pure. M. de Morveau likewise succeeded in cuppelling a mixture of one drachm of platina, and two drachms of lead, in the wind furnace of Macquer: this operation, made at four successive times, lasted eleven or twelve hours. M. de Morveau obtained a button of platina, not adhering to the cuppel, uniform, of a colour resembling tin, but rather rough, which weighed exactly one drachm, and was found to be not at all acted on by the magnet. This process appears to be excellently adapted for obtaining platina in plates or laminae, which may be forged, and consequently may be employed in making various utensils of great value, with respect to hardness and unchangeableness. M. Baumé has likewise observed another very useful property, viz. that of welding and forging together, like iron, without the assistance of any other metal. After having heated two pieces of platina to whiteness, which had been cuppelled in the furnace of Seyes, he placed them one on the other, and striking them

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them briskly with the hammer, they welded together as quickly and firmly as two pieces of iron would have done. The great importance of this experiment, with respect to the arts, need not be insisted on.

Macquer could not obtain an alloy with forged iron and platina: this mixed metal would possess the great advantage of uniting the hardness of steel with a considerable ductility, or at least it would not be brittle like steel. The English chemist we have quoted melted a mixture of cast iron and platina; the alloy was so hard as not to be touched by the file; it had a slight degree of ductility, but broke short when ignited. Platina communicates hardness to copper, with which it melts with considerable facility: this alloy is ductile, when the dose of copper is three or four times greater than that of platina; it is capable of taking the most beautiful polish, and was not tarnished in the air during the space of ten years.

Platina partly destroys the ductility of silver, augments its hardness, and impairs its colour. This mixture is very difficult to fuse; by fusion and rest the two metals are separated. Lewis observed, that silver melted with platina was thrown up against the sides of a crucible, with a kind of explosion; a property which appears to belong to silver alone; for M. Darcet has observed that this metal breaks balls of porcelain,

lain, in which it is inclosed, and is thrown out by the action of the fire.

Platina does not readily combine with gold, but by the help of a very strong fire. It greatly alters the colour of this metal, unless its quantity be very small; thus, for example, a forty-seventh part of platina, and all the proportions below that, do not greatly change the colour of gold. Platina does not much impair the ductility of gold, which is less affected than any other metal by the admixture. The specific gravity of platina being nearly equal to that of gold, might give rise to frauds; and for this reason the Spanish ministry have prohibited its exportation: however, since chemistry has discovered methods for distinguishing the alloy of gold with platina, and even of platina alloyed with gold, these fears ought no longer to be attended to; and it is much to be desired, that platina may no longer be prohibited, but that this new metal, which promises such considerable advantages to society, may become an article of commerce.

The solution of sal-ammoniac, as we have observed, has the property of precipitating platina; if, therefore, gold be suspected to be alloyed with platina, its solution in aqua regia may be assayed with a solution of sal-ammoniac. The small quantity of platina it contains will occasion an orange, or reddish precipitate; if no precipitate is thrown

down, the gold does not contain platina. If it should happen, that the valuable properties of platina should at some future time render it more scarce and valuable than gold, it will not be in the power of avarice to deceive us in alloying it with gold; since a solution of martial vitriol, which has the property of precipitating the solution of gold without producing any change in that of platina, would immediately expose the deception. A piece of tin, plunged in a solution of platina alloyed with gold, would likewise shew the presence of the latter, by becoming covered with a purple precipitate; whereas platina gives only a dirty brown precipitate, of a reddish colour: this last precipitate likewise does not colour glass, whereas the precipitate of gold gives it a purple colour.

All the properties of platina, which we have examined, appear to prove that this substance is a peculiar metal: its want of ductility and fusibility, which have been considered by some writers as strong objections to this opinion, are not capable of overthrowing it; since there is perhaps a less difference between the fusibility of platina and forged iron, than between that of forged iron and lead, and since its want of ductility arises from its not having undergone complete fusion. As to the opinion of those philosophers, who consider
platina

platina as a natural alloy of iron and of gold, however ingenious and satisfactory it may appear, it is impossible to admit it, until the metal has been separated into the two others by an accurate analysis, and until platina can be better imitated by the artificial alloy of gold and iron. Lastly, Macquer has made a very strong objection against this last opinion, by observing, that the more platina is deprived of the iron it contains, the greater is the difference between its external appearances and those of gold.

The important uses to which this precious metal may be applied, will be easily conceived, when it is considered that it unites the indestructibility of gold, to a degree of hardness almost equal to that of iron; that it resists the action of the most violent fire, and also of the most concentrated acids. It cannot be doubted, but that chemistry, and the arts, would be in the highest degree benefited by its being applied to useful purposes.*

* Platina, when purified from iron by repeated coction in spirit of salt, solution in aqua regia, and precipitation of the iron by aqua regia, may be fused with a strong heat. It may then be rolled into thin plates, seems nearly as malleable as soft iron, is scarcely distinguishable from silver on the touch-stone, does not at all obey the magnet, and has a specific gravity of nearly 23,000. T.

C H A P. XXII.

G E N U S VI.

Concerning Bitumens in general.*

BITUMENS are combustibile, solid, soft, or fluid substances, whose smell is strong, acrid, or aromatic, and which appears to be much more compounded than those bodies of the mineral kingdom we have hitherto examined. They are found either in strata, in the internal part of the earth, or exuding through the clefts of rocks, or floating on the surface of waters. Their character is to burn most commonly with a rapid flame when heated with contact of air, like those matters formed by the organs of vegetables and animals, and distinguished by the name of oils. Their analysis is much less perfect than that of earthy, saline, or metallic matters; because the action of fire greatly alters them, and developes principles which re-act on each other, in proportion as they are volatilized. In this respect bitumens resemble vegetable and animal substances. By distillation they afford water, or

* It is proper to remind the reader that we have divided combustibile minerals into six genera, viz. Diamond, inflammable gas, sulphur, plumbago, metals and bitumens. F.

an odorous phlegm, more or less coloured, a saline acid salt, often concrete, sometimes volatile alkali and oils, light towards the beginning, and more thick and coloured in proportion as the distillation advances, and the fire is more active. After this analysis a coal remains, which in the different species of bitumens is either dense, light, brilliant, or compact. This analysis shews, that these inflammable substances have a vegetable or animal origin, as we shall observe more fully after we have spoken of their general properties.

Bitumens are subject to some alterations from light. When fluid, their colour becomes deeper, and their smell is changed, if preserved in transparent vessels. The air thickens them by the successive evaporation of their moisture, which is taken up so much the more readily as the air is drier. Their odorous principle, or spiritus rector, is dissipated in the same manner, as they gradually pass from the state of fluidity to that of tenacity and solidity. A great number of years however are necessary to produce this last alteration.

Water, in which bitumens are boiled, does not dissolve them, but it becomes charged with their spiritus rector, and emits the peculiar smell of the bitumen. It seems, therefore, that water has a stronger affinity with the odorant principle, than the oily matter

matter of the bitumen ; and that the whole smell of these substances might perhaps be taken away in this manner.

The action of the salino-terrestrial substances on bitumens has not yet been examined ; lime, however, as well as pure alkalis, seems capable of uniting with these combustible matters, and forming compounds soluble in water, which are called soaps.

The manner in which the mineral acids are capable of acting on bitumens, is not known. It is probable, that they would dissolve or burn them according to their state of concentration, as they do oils.

The action of neutral salts, of inflammable gas, of sulphur, and of metals, on bitumens, has not been examined ; and in general the chemical properties of these substances are but little known. This field of experiment is intirely new, and certainly promises valuable and useful results.

Natural historians have paid a much greater attention to the origin and formation of bitumens, than chemists have to their analysis. There have been many opinions respecting this subject. Some have thought that these combustible substances properly belong to the mineral kingdom, and that they have the same relation to minerals, as oils and resins have to organic substances. This analogy, though striking to the imagination, does not agree with the facts, for there is

no substance in the mineral kingdom which possesses the oily character. The opinion of those therefore, who attribute the origin of bitumens to vegetable substances buried in the earth, and altered by the action of mineral acids, has met with a much better reception. In fact, every circumstance proves, that bitumens are produced from organic substances. A great number of bodies of this kind, whose form is still distinguishable, is constantly found in their vicinities; they have, besides, the chemical characters of substances formed by the processes of animation, and have been imitated, in a certain degree, by combining oils with the concentrated vitriolic acid. We shall see in the chemical history of vegetable substances, that oil of vitriol in contact with essential oils, hardens and blackens them, and communicates to them a strong and penetrating smell, resembling that of bitumens. But can it be asserted that these substances are in all cases formed by vegetable substances buried in the earth, as most naturalists have affirmed, and that animal substances have contributed nothing to their formation? The great quantity of bitumens which exist in the external part of the earth, compared with the small quantity of wood and of trees found in their vicinity, and more especially the small proportion of oily matter contained in vegetables, seem to contradict that opinion which attributes the origin
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of bitumens solely to productions of the vegetable kingdom; on the other hand, the abundance of these combustible bodies in places where scarcely any traces of vegetables are found, and the almost constant existence of the exuviae of animals heaped above bitumens, may induce us to believe, that these organic beings have contributed greatly, and perhaps even more than vegetables, to the formation of some of the kinds. We may likewise observe, that the successive strata of certain bitumens which are found in continued masses in the internal part of the globe, prove, that these substances have been deposited slowly, and by means of water; and that their formation corresponds to the æra in which immense masses of shells, or other marine substances, have been formed by the sea. They have, therefore, been in a fluid state, and are become hard by the lapse of time and the unremitted action of saline, or other agents, which the interior part of the earth contains in large quantities. Such is the opinion which M. Parmentier, member of the College of Pharmacy has exhibited, respecting the origin of pit-coal, in a memoir which he read at the opening of the course of lectures before that Society. The oils and fats of marine animals appear, therefore, to be one of the matters used by nature in the formation of certain bitumens; while there are others, whose

whose origin is manifestly vegetable, and arises from the resins or essential oils, buried and changed in the earth.

The number of bitumens is very considerable. Naturalists have divided them into several genera. As we here consider them chemically, we shall divide them into species or kinds; because they have all, in fact, the same characters relative to their chemical properties; some are liquid, others are of a soft consistence, and others are solid, among which last some are hard and susceptible of a polish, while others are friable. We are acquainted with six species, very distinct from each other, which may comprehend a great number of varieties. These six species, whose history we shall proceed to recite, are amber, asphaltos or bitumen Judaicum, jet, pit-coal, ambergris, and petroleum.

C H A P. XXIII.

S P E C I E S I.

Amber.

AMBER, the most beautiful of all the bitumens, is found in irregular masses of a yellow or brown colour, either transparent or opaque, of a stratified or scaly texture;

texture ; it takes a very good polish ; after a slight rubbing it becomes electric, and attracts straws and small bodies. The ancients, who were acquainted with this property, gave amber the name of electrum, whence the modern term electricity is derived.

This bitumen is of a considerable hardness, approaching to that of certain stones, which induces Hartman, a naturalist who lived towards the conclusion of the last century, to rank it among precious stones, though it is friable and brittle. When pulverized it emits an agreeable smell. Insects, in a fine state of preservation, are often found within it, which proves that it has been liquid, and in that state has enveloped those small bodies. Amber is usually dug out of the earth at various depths ; it is found under coloured sands in small incoherent masses, and dispersed on strata of pyritaceous earth : above it wood is usually found, charged with blackish bituminous matter ; whence it has been concluded, that it is formed by a resinous substance altered by the vitriolic acid of pyrites. It likewise is found floating on the banks of the sea ; as for example, on the shores of the Baltic in Ducal Prussia. The mountains of Provence near the town of Sisteron, the Marquisate of Ancona and the Duchy of Spoleto in Italy, Sicily, Poland, Sweden, and many other countries likewise afford it. The colour, texture, transparency,
or

or opacity of this bitumen, have caused it to be distinguished into a considerable number of varieties, which, after Wallerius, we may reduce to the following :

Varieties.

1. White transparent amber.
2. Pale yellow transparent amber.
3. Orange yellow transparent amber.
4. Golden yellow transparent amber, chryseletrum of the ancients.
5. Deep red transparent amber.
6. Opake white amber, leuceletrum.
7. Opake yellow amber.
8. Opake brown amber.
9. Amber, coloured green or blue by foreign substances.
10. Veined or clouded amber.

It may likewise be distinguished into a great number of varieties, according to the accidental circumstances its internal parts present ; but it is necessary to observe, with respect to the price of the specimens of amber remarkable for their magnitude, their transparency, or the well preserved insects contained within them, that it is possible to be deceived in this respect, since many persons possess the art of giving it transparency or colour at pleasure, and of softening it sufficient to introduce foreign bodies. Wallerius affirms, that the gold-coloured amber never owes its transparency to art, but that which

which art has rendered transparent, is always of a pale colour.

Though it is probable that this bitumen owes its origin to resinous vegetable matters, many naturalists have entertained different opinions respecting its formation; some have considered it as the indurated urine of certain quadrupeds; others as a bitumen detached from the earth by the sea, which is become hard and dry by the action of the sun's rays. This class of naturalists consider it as a peculiar mineral juice; such was the opinion of an ancient naturalist named Philemon, and quoted by Pliny. George Agricola revived this opinion; Frederic Hoffman supposed it to be formed out of a light oil, separated from bituminous woods by heat, and thickened by the vitriolic acid. This opinion of Hoffman cannot, however, be admitted, because it is not conceivable how an oil separated in the bowels of the earth, can inclose and contain animals which live only at its surface. It has hitherto been thought, that amber is a resinous juice which flows from some tree; that this juice, buried more or less deeply in the earth, by the convulsions the globe has experienced, becomes hardened by impregnation with the mineral and saline vapours which circulate within the earth. It is not probable that it has been altered by concentrated acids; for experience teaches us, that the action of these acids would have blackened
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ed it, and converted it into the state of coal. Pliny thinks that amber is nothing but the resin of the pine, hardened by cold. M. Girtanner thinks, that it is a vegetable oil rendered concrete by the acid of ants; it is that species of ants called *formica rufa* by Linnæus, which prepares it, according to this author. These insects dwell in old forests of fir trees, where the fossil amber is found, which is ductile like wax, and becomes hard by exposure to air.

Amber, exposed to the fire, does not liquefy, but by a considerable heat it softens and swells very much; when heated with contact of air it takes fire, and emits a very thick and odorous fume; its flame is yellowish, variegated with green and blue; and after its combustion it leaves a bright black charcoal, which by incineration affords a very small quantity of black brown earth. Bourdelin, in his Memoir on Amber, (*Acad.* 1742) obtained but 18 grains of this earth by burning two pounds of amber; half a pound of the same bitumen burned and calcined in a crucible, afforded him, in a second operation, twelve grains of earthy residue, from which he extracted iron by the magnet.

Amber distilled in a retort by a heat gradually raised, affords a phlegm of a red colour, and manifestly acid; this acid spirit retains the strong smell of amber: an acid volatile

salt afterwards passes over, which crystallizes in small white, or yellowish needles in the neck of the retort. This salt is succeeded by a white and light oil of a very penetrating smell; the oil by degrees becomes coloured in proportion as the heat is raised, and towards the end is brown, blackish, thick, and viscid, like the empyreumatic oils: while these two oils pass, a certain quantity of volatile salt, more and more coloured, is sublimed. The residue after this operation is a black mass of the figure of the bottom of the vessel, brittle, and resembling bitumen Judaicum. George Agricola made the same observation near three centuries ago, on the residue of distilled amber. If the operation be managed by a gentle heat, cautiously conducted, and the quantity of amber be considerable, these products may all be obtained separately, by changing the receivers. It is usual however to receive them in the same vessel, and afterwards to rectify by a gentle heat; the spirit is partly discoloured by this rectification. The oil which becomes black at the end of the operation, on account of the carbonaceous portion, and because the acid has acted on its principles, may be rendered very clear and light by several successive distillations. Rouelle the elder has described a very good process for obtaining it in this state by one operation: for this purpose the oil must be put into a
glass

glass alembic with water, and distilled by the heat of boiling water; the purest portion, or the oily part which is volatile at this degree of heat, on account of its levity, passes over with the water, above which it floats in the receiver: if it be designed to preserve it in this state, it must be kept in vessels of stone-ware; for the rays of light which pass through glass vessels give it a yellow, and even a brown colour in process of time.

This analysis shews, that amber consists of a large quantity of oil rendered concrete by an acid, and that it likewise contains a very small quantity of earth, whose nature has not been yet examined, with a few particles of iron.

The oil of amber appears to resemble essential oils in volatility, smell, and inflammability: it seems capable of forming soaps with alkalies.

The volatile salt of amber was for some time considered as an alkaline salt. Glaser, Lefevre, Charas, and Jean-Maurice Hoffman, professor at Altdorf, were of this opinion. Barchusen, and Bolduc the elder, were the first chemists, who in the last century observed the acid nature of this salt. All subsequent chemists have admitted this discovery, but they have not agreed concerning the nature of the acid. Frederic Hoffman, from the consideration that amber is found in Prussia among the strata of metals filled with pyrites, imagined that this salt is formed from

the vitriolic acid. Neumann appears to be of the same opinion. Bourdelin, in the Memoir we have quoted, relates several experiments he made to determine the nature of this salt: He first observes, that the salt of amber obtained by distillation, however white and pure it may appear, always contains an oily substance; and it is doubtless to this oily substance, that its smell, and the degree of combustibility it exhibits when thrown on burning coals, are owing: he tried several methods of depriving it of this substance. We shall see when we examine the nature and properties of ardent spirit, that this fluid could not answer his purpose; neither was the fixed alkali alone which he digested on amber with the intention of depriving it of its fat and oily part, and of obtaining its salt separate, attended with greater success; it only dissolved a small quantity of the bitumen, and assumed a lixivial and saline taste, resembling that of sea salt. Lastly, Bourdelin could not discover a better process for uniting the pure acid of amber, deprived of oily matter, with fixed alkali, than to detonate a mixture of two parts of nitre with one part of the bitumen: he lixiviated the residue of this detonation with distilled water; the lixivium was of an amber colour, precipitating the solution of silver in white scales, and that of mercury of the same colour. Many other metallic solutions were likewise

likewise decomposed by it, but Bourdelin considered only the two first as conclusive: they appeared to him to shew, that the acid of amber was the same as that of marine salt, since it presented the same phenomena as this last with the nitrous solutions of mercury and silver. The lixivium of the residue of the detonation of amber with nitre afforded, by evaporation in the air, a mucilaginous substance, in the middle of which square long crystals were deposited; whose form, saline taste, decrepitation on hot coals, and more particularly the considerable effervescence and odour of marine acid, which they emitted by the affusion of oil of vitriol, convinced this author that spirit of salt was united with the base of nitre. Notwithstanding this analysis, which is very exact for the time of Bourdelin, the chemists who examined the salt of amber since his time, did not find it analogous to the muriatic acid, but discovered in it all the characters of an oily vegetable acid. Bergman, who appears to have adopted this opinion, gives the following account of the elective affinities of this salt. The acid of amber obtained by sublimation, and purified by successive solutions and crystallizations, forms crystallizable and deliquescent neutral salts, with potash and volatile alkali; with soda it affords a salt which does not attract the moisture of the air; with lime or barytes, it constitutes

salts of difficult solubility; magnesia forms with it a thick matter, resembling gum; it dissolves metallic calces; and the salts produced by these solutions are for the most part crystallizable and permanent.

Ponderous earth, lime, and magnesia, according to him, take the acid of amber from alkalies; ponderous earth decomposes succinated lime and magnesia; and lime-water precipitates the magnesia from this acid.

The examination of the chemical properties of this bitumen has not been carried farther; it is not even known in what manner the other acids act upon it. Frederic Hoffman affirms, that it may be totally dissolved in a lixivium of caustic alkali, and in the acid of vitriol. It is known, that the essential oil of amber unites with the caustic volatile alkali, and forms by simple mixture and agitation a kind of liquid soap, of a milky white, and very penetrating odour, known in pharmacy by the name of Eau de luce; and lastly, that this same oil dissolves sulphur by the assistance of the heat of a water-bath, and constitutes a medicine called succinated balsam of sulphur.

Amber is used in medicine as an antispasmodic; it has been recommended in hysteric and hypochondriacal affections, the suppression of the monthly courses, the gonorrhœa, fluor albus, &c. It is used in substance, after

after having been washed with hot water, and reduced into fine powder by levigation; it is used in strengthening and resolving fumigations, by throwing the powder of this bitumen on a very hot brick, and directing the fumes to the part proposed to be acted on. The volatile spirit and incisive salt of amber are regarded as cordial and antiseptic. The oil of amber is externally and internally used for the same purposes as amber itself, but is prescribed in smaller doses, on account of its greater activity. The succinated balsam of sulphur, which is given in the dose of a few drops, in proper fluids, or mixed with other substances to form pills, is found successful in pituitous affections or defluxions of the breast, the reins, &c. A syrup, called syrup of amber, is made with spirit of amber and opium, and advantageously used as a sedative, anodyne, and antispasmodic remedy. Eau de luce, which is prepared by pouring a few drops of oil of amber into a bottleful of caustic volatile alkali, and agitating the mixture till it becomes of a white milky colour, has been long used as a powerful stimulant in fainting fits. It is held to the nose, whose nerves it stimulates, and by the sneezing which it excites, the fluids are put in motion, and the patient recovers.

The finest pieces of amber are cut and turned into vases, heads of canes, necklaces,

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bracelets,

bracelets, snuff-boxes, &c. These kinds of toys are no longer esteemed among us, since diamonds and jewellery are become more known; but they are carried into Persia, China, and other nations, who still esteem them as great rarities. Wallerius affirms, that the most transparent pieces may be used to make microscopes, burning glasses, prisms, &c. It is affirmed, that the King of Prussia has a burning mirror of amber, of a foot in diameter; and that there is a column of amber, ten feet in height, and of a beautiful lustre, in the cabinet of the Duke of Florence. Two pieces of this bitumen may be stuck together, by smearing them with oil of tartar, and pressing them together hot.

C H A P. XXIV.

S P E C I E S II.

Asphaltos.

ASPHALTOS, or bitumen Judaicum, is a black, ponderous, solid shining bitumen which breaks readily with a vitreous fracture. A thin piece of this bitumen appears red, when placed between the eye and the light. Asphaltos has no smell when it is cold, but acquires a slight smell by rubbing. It is found on the waters of the lake Asphaltites,

tites, or the Dead Sea, in Judea, near which were the ancient towns of Sodom and Gomorrah. The inhabitants, incommoded by the smell emitted by this bitumen on the surface of the waters, and allured by the profit they derive from it, are careful in collecting it. Lemery, in his *Dictionnaire des Drogues*, affirms, that the asphaltos sweats out of the earth, in the form of a liquid pitch; and rising above the waters of the Dead Sea, is condensed by the heat of the sun, and the action of the salt, which those waters contain in large quantities. It is likewise found in several lakes in China.

The asphaltos in commerce, is obtained, according to Valmont de Bomare, from the mines of Daunemore, and especially in the principality of Neufchatel and Wallengin. It is of two colours, according to this naturalist, blackish and greyish or fawn-colour; but this asphaltos is far from being pure, and seems to be merely an earth, hardened and penetrated by the bitumen.

Naturalists are divided in their opinion respecting the origin of asphaltos, as well as of all other kinds of bitumen: some suppose it to be a mineral product, formed by an acid, united with a fat substance, in the bowels of the earth; others consider it as a vegetable resinous substance buried, and altered by the mineral acids. The most generally received, and most probable opinion, is,

is, that it has the same origin as amber, and is formed of this last bitumen, changed by the action of subterraneous fires. This opinion is founded on the circumstance, that amber, melted and deprived of a part of its salt by the action of fire, becomes brittle, and perfectly similar to asphaltos: but this doctrine cannot be solidly established, but by a comparative analysis of this residue of amber, and of asphaltos; and the latter bitumen has not been yet examined with all the accuracy which is necessary to establish the analogy.

Asphaltos, exposed to heat, liquefies, swells up, and burns with a flame and thick smoke, whose smell is strong, acrid, and disagreeable: by distillation, it affords an oil of the colour of brown petroleum, and an acid phlegm.

Asphaltos is employed by the Arabians and Indians for the same purposes as pitch, in coating their vessels, &c. It enters into the composition of the black varnish of china, and the artificial fires which burn on the surface of water. The Egyptians used it to embalm their dead; but it was not employed by the poor, who could not procure such precious antiseptic substances. Wallerius affirms, that a kind of asphaltos is prepared, in commerce, with thickened pitch, or by mixing and melting the latter with a certain quantity of the true balsam of Judea; but
this

this fraud may be discovered by means of spirit of wine, which intirely dissolves the pitch, and only takes a pale colour with asphaltos.

C H A P. XXV.

S P E C I E S III.

Jet.

JET, called by the Latins *gagas*, black amber by Pliny, *pangitis* by Strabo, &c. is a black bitumen, hard and compact, like certain stones; brilliant and vitreous in its fracture, and capable of taking a good polish by friction: it attracts light substances, and appears to be electric, like amber: it has no smell, but when heated, it acquires one nearly resembling that of bitumen *Judaicum*.

Jet is found in France, in Provence, and in the county of Foix; there is likewise a quarry where it is extracted at Belestat, in the Pyrenean mountains; it is likewise found in Sweden, Germany, and Ireland. Jet is found disposed in strata which contain pyrites, in which it resembles the strata of coal, and most other bitumens.

This bitumen softens and melts, when strongly heated, it burns with a fetid odour; by distillation it affords an oil and an acid.

Among

Among the different opinions respecting the formation of jet, the most probable is that which supposes it to consist of asphaltos, hardened by time: this opinion has been adopted by the learned Wallerius.

Jet is used to make mourning toys. It is wrought, at Wirtemberg, into bracelets, buttons, boxes, &c.

C H A P. XXVI.

S P E C I E S IV.

Pit-Coal.

THE name of fossil-coal, pit-coal, stone-coal, lithantrax, &c. is given to a black foliated bituminous matter, either of a bright or dull appearance, which easily breaks, and has neither the consistence nor the purity of the bitumens before described.

This bitumen has received the name it bears, in consequence of its combustible property, and the uses it is applied to in many countries. It is found within the earth, below stony beds of various degrees of hardness, and alluminous and pyritaceous shisti. The latter constantly bear the print of several vegetables of the family of fern, most of which, according to the observation of Bernard de Jussieu, are exotic.

Pit-

Pit-coal is found at various depths within the earth; it is disposed in horizontal or inclined strata, the latter disposition being the most usual; the beds, or strata of which it is composed, differ in thickness, consistence, colour, weight, &c. Beds of shells, and fossil madrepores, are often observed above the strata of this bitumen, which has induced several moderns, particularly M. Parmentier, to conclude that pit-coal has been formed in the sea, by the deposition and alteration of oily or fat marine substances. Most naturalists consider it as the product of a residue of woods buried in the earth, and altered by acids.

The mines of fossil-coal are wrought in the same manner as other mines, by digging shafts and drifts, and detaching the pieces of this bitumen by pick-axes. The miners are often exposed to the danger of losing their lives by the elastic fluids which are disengaged. The kind of mephitic called choak-damp extinguishes their candles, and appears to be the cretaceous acid; a kind of inflammable gas is likewise developed in mines, which sometimes produces dangerous explosions.

Fossil-coal is very abundant in nature; it is found in England, Scotland, Ireland, Heineault, Liege, Sweden, Bohemia, Saxony. Many provinces in France afford it in abundance,

dance, especially Burgundy, Lyons, Forez, Auvergne, Normandy, &c.

Fossil-coal is distinguished into stone-coal, or earthen coal, according to its hardness and friability; but the manner in which it burns, and the phenomena it presents during its combustion, afford characters much better adapted to distinguish the different sorts. Wallerius distinguishes three sorts under this point of view: 1. The scaly coal, which remains black after its combustion. 2. The compact and laminated coal, which after having been burned, affords a spongy matter, similar to scoriæ. 3. Fibrous pit-coal, resembling wood, which is reduced into ashes by combustion.

This bitumen, heated in contact with the air, burns more slowly and difficultly, in proportion as it is more heavy and compact. When once perfectly set on fire, it emits a strong and durable heat, and is long before it is consumed; it may even be extinguished, and used several successive times for new combustions. Its inflammable matter appears to be very dense, and as it were fixed by another incombustible substance, which prevents its dissipation. It emits a peculiarly strong smell, which, however, is not at all sulphureous. When the coal is very pure, and does not contain pyrites, the combustion of this bitumen appears to resemble that of organic substances, particularly in the circumstance

cumstance of its being capable of being interrupted, and burned again. In fact, the most volatile, oily, and most combustible part of pit-coal, is dissipated and inflamed by the first action of the heat; and if the combustion be extinguished when this principle is dissipated, the bitumen retains no more than the most fixed and least inflammable part of its oil, reduced into a true coaly state, and combined with an earthy base. By a process of this nature the English prepare their coke, which is pit-coal, deprived of its oily fluid by the action of fire. What happens in this experiment is easily shewn, by heating the bitumen in closed vessels, with the proper apparatus for distillation: an alkaline phlegm, concrete volatile alkali, and an oil, which becomes of a deeper colour, and more heavy, in proportion as the distillation advances, are obtained; at the same time that a great quantity of elastic and inflammable fluid is disengaged, which is supposed to be oil in the vapourous state, but is in fact a peculiar kind of inflammable gas: in the retort there remains a scorified carbonaceous matter, still capable of burning, which is the coke of the English. If the action of fire on pure pit-coal be attended to, it is seen that, it suffers an evident softening, and appears to undergo an imperfect fusion; and as this state might be prejudicial to the fusion of ores, it is necessary to deprive the coal of this property:
the

the principle on which the softening depends being taken away, namely, the oil which it contains in great abundance, the coal is reduced into a state analogous to that of charcoal made with vegetables. We must not forget to observe, that the volatile alkali, abundantly furnished by pit-coal, favours the opinion we have urged respecting its animal origin, since, as we have elsewhere seen, the substances afforded by the animal kingdom always afford this salt by distillation. This analysis of coal is made in the large way in many parts of England; and the different products of pit-coal are collected in a peculiar distillatory apparatus: the oil is employed instead of pitch, the volatile alkali serves the manufactories of sal-ammoniac, and the residue is an excellent coke. M. Faujas de Saint Fond has transported this useful art into France, and the experiments he has made at the King's Garden have succeeded perfectly well.*

* Every principle of justice and equity demands that the name of Lord Dundonald should not be passed over in silence when this art is spoken of. It is this gentleman, who, having the spirit to risque his fortune on a rational and highly beneficial project, has done more service to his country, and mankind at large, than if he had discovered an hundred gold mines. The coke and mineral tar are of infinite utility in the arts; but I do not know whether the volatile alkali of this process is cheaper than that usually obtained from bones, nor whether the oil is applied to the commercial purposes. T.

Pit-

Pit-coal is singularly useful in countries where wood is scarce: it is employed as fuel without any of that danger attributed by certain persons to its use; for the sulphureous vapour, which has been said to be spread abroad during its combustion, is not to be feared, since the most accurate analysis has proved, that when pit-coal is very pure, it does not contain the smallest portion of sulphur. Hence we may perceive how false and fallacious are the pretences of certain ignorant persons, who affirm that they are in possession of processes to deprive this bitumen of its sulphur. Another consideration which ought to engage us, especially in France, to use pit-coal, is, that the mine-works consuming immense quantities of charcoal, there is reason to fear that wood will, at no very distant period of time, become scarce; and it is more especially in those kinds of works that pit-coal ought to be used, as it long has been by the English.

Purified pit-coal consists of coal deprived of its oil by the action of fire; this kind of charcoal burns without smoke, without becoming soft, and without emitting any strong smell: in a word, it is a true coke, and is preferable as fuel to be burned in the apartments of a dwelling house.

One of the greatest inconveniences of pit-coal, besides the very abundant and thick smoke it emits, and which blackens furniture,

is, that the very rapid and abundant current of air it requires for its combustion raises and volatilizes part of its ashes, which fix themselves to the surrounding bodies; but these two inconveniences may in a great measure be remedied by well-constructed chimnies, so that the current excited by the combustion may be intirely carried out of doors, without any part of it returning into the chamber.

The utility which this combustible substance will be of in France, is much greater with respect to the arts and manufactures of every kind; and by availing ourselves of this fuel, wood for building, and other purposes, will be rendered cheaper.

C H A P. XXVII.

S P E C I E S V.

Ambergris.

AMBERGRIS is a concrete substance, of a soft and tenacious consistence, like wax, marked with black and yellow spots, and of an agreeable and strong smell when heated, or rubbed: it is in irregular masses, sometimes rounded, consisting of layers of different kinds, more or less thick, accordingly as they are united in great numbers. Pieces have

have been found weighing more than two hundred pounds: this substance has manifestly been liquid, and has enveloped many foreign matters; such as the bones of the cuttle fish, and other marine animals.

Ambergris is found floating on the sea, near the Molucca islands, Madagascar, Sumatra, on the coast of Coromandel, Brazil, America, China, and Japan. Many American fishermen assured Dr. Schwediawer, that they often found this substance, either among the excrements of the species of whale, called by Linnæus *phyfeter macrocephalus*, or in its stomach, or in a vessel situated in that region.

Naturalists distinguish many varieties of ambergris: Wallerius admits the six following.

Varieties.

1. Ambergris spotted with yellow.
2. ——— spotted with black. These two varieties are the most valuable.
3. Ambergris of an uniform white.
4. ——— of an uniform yellow.
5. ——— of an uniform brown.
6. ——— of an uniform black.

It must be observed, that these varieties depend on the mixture of certain marine substances.

The learned have been greatly divided in their opinion respecting the origin of ambergris.

bergris. Some consider it as a kind of petroleum, issuing out of the rocks, thickened by the action of the sun, and of the salt-water: others have supposed it to be the excrements of birds, which feed on odorous plants; others again have attributed its origin to the excrement of the sea-cow, or of the crocodile, &c. Pommet and Lemery supposed it to be a mixture of wax and honey, altered by the sun and the sea-water. M. Formey, who adopted this opinion, has supported it by an experiment, which consists in digesting a mixture of wax and honey; he affirms, that a sweet smell, very much resembling that of amber, is emitted by the product. Some English writers have considered ambergris as an animal juice, deposited in vessels placed near the origin of the genital parts of the male whale; and others have supposed it to be formed in the urinary bladder of that creature: but both these opinions are overthrown by the beaks of the cuttle fish, found in this concrete matter. Lastly, M. Schwediawer, after examining a great number of specimens of ambergris, and inquiring into the reports of several navigators, thinks that this substance is formed in the alimentary canal of the *physeter macrocephalus*, or species of whale from which spermaceti is obtained. He considers ambergris as the excrement of this creature, mixed with certain parts of its nourishment.

nourishment. 1. Because the fishermen found it in that whale. 2. Because ambergris is common in those regions which abound with this fish. 3. Because the beak of the sepia octopoda, on which this animal feeds, are always contained in it. 4, and lastly, Because he has observed that the black spots of this concrete substance are the feet of that polypus. His inquiries have rendered this opinion of the Japanese, and of Kempfer, the most probable; and nothing is now wanting for its intire confirmation, but the observation of some real naturalist, made on the spot.

Nevertheless, this substance, analyzed by Geoffroy, Neumann, Grim, and Brown, afforded the same principles as bitumens; that is to say, an acid spirit, a concrete acid salt, oil, and a carbonaceous residue, which induced them to rank it among those bodies. But M. Schwediawer observes very truly, that the calculi of animals afford an acid, and that the presence of this salt is a proof in favour of his opinion, since fats contain it in considerable quantities.

Ambergris is stomachic, cordial, and antispasmodic. It is used in the dose of a few grains, in proper liquids, or mixed with other substances, in the form of pills. The odorous principle of this medicine is often too strong and penetrating, so as to be productive of noxious effects. It is well known, that

many persons cannot endure its smell, without experiencing all the disagreeable symptoms which arise from nervous irritation: it ought not therefore to be administered but with precaution. It has likewise been regarded as a powerful aphrodisiac: some modern physicians, however, think that ambergris may be prescribed in large doses, without producing any considerable effects.

The principal use of ambergris is to afford a perfume for the toilet. It is usually mixed with musk, which divides and attenuates its smell in such a manner as to render it more supportable; but even in this state there are many who dislike it.

As ambergris is an expensive substance, it is often adulterated, and mixed with various other matters. True ambergris has the following characters: it is flaky, of a sweet smell, and insipid; it melts without affording either bubbles or scum, when exposed to the flame of a taper in a silver spoon; it floats upon water, and does not adhere to a hot iron. Ambergris, which does not possess all these properties, is impure and adulterated.

C H A P. XXVIII.

SPECIES VI.

Petroleum.

THE name of petroleum is given to a liquid, bituminous substance, which flows between stones or rocks, or in different places at the surface of the earth. This oil differs in lightness, smell, consistence, and inflammability, in its several specimens. Authors have distinguished a considerable number of varieties: they have given the name of naphta to the lightest, most transparent, and most inflammable petroleum; the name of petroleum, properly taken, is applied to a liquid bitumen, rather thick, and of a deep brown colour; and lastly, that of mineral pitch is used to denote a black thick bitumen, scarcely liquid, but tenacious, and sticking to the fingers. The following varieties are described by Wallerius, and many other naturalists.

Varieties.

1. White naphta.
2. Red naphta.
3. Green, or dark-coloured naphta.
4. Petroleum, mixed with earth.
5. Petro-

5. Petroleum exsuding from between stones.

6. Petroleum floating on the surface of waters.

7. Mineral pitch or Malta.

8. Pissasphaltum. It is of a middle consistence, between that of common petroleum and asphaltos, or bitumen Judaicum.

The different naphtas are found in Italy, in the duchy of Modena, and at Mount Crocchio, twelve leagues from Plaisance. Kempfer reports, in his *Amœnitates Exoticae*, that it is collected in large quantities in several parts of Persia. Petroleum is found in Sicily, and many other parts of Italy; in France, and the village of Gabian in Languedoc; in Asia; at Neufchatel in Switzerland; in Scotland, &c. The pissasphaltum and mineral pitch were formerly brought from Babylon, where it was used in the construction of edifices; from Ragusa in Greece, and the Tank or pond of Samoset, capital of Comagena in Syria. It is at present obtained from the principality of Neufchatel and Wallengin; from the Well de la Pege, one league from Clermont-Ferrand in Auvergne; and several other places. It must be observed, with respect to the different varieties we have pointed out, that they all appear to have the same origin, and differ from each other only in some particular modification. Most naturalists and chemists attribute

attribute the formation of petroleum to the decomposition of solid bitumens by the action of subterraneous fires. They observe that naphta appears to be the lightest oil, which is first disengaged by the fire; and that which succeeds it, acquiring colour and consistence, forms the different kinds of petroleum: that, lastly, these united to earthy substances, are altered by acids, and assume the characters of mineral pitch, or pissasphaltum. In support of these opinions, they have made a very accurate comparison between these phenomena, and those which the distillation of amber presents, which in fact affords a kind of naphta, a petroleum more or less brown, according to the degree of heat, and time of the operation. And lastly, they observe that nature often presents in the same place other kinds of petroleum, from naphta, the lightest, down to the mineral pitch: such are the fluid bitumens obtained from Mount Festin, in the duchy of Modena. Though this opinion is very probable, some authors think that petroleum is a mineral, oily combination, formed by the vitriolic acid and some fat substance; but this combination likewise would owe its origin to certain organic substances, since fat matters are always formed by such.

The chemical properties of petroleum have not yet been examined. Naphta is so volatile and combustible, that it takes fire
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on the approach of any burning substance, and seems even to attract flame, on account of its volatility: the brown petroleum affords an acid phlegm, an oil, which at first resembles naphta, and becomes more dense and coloured, in proportion as the distillation advances: a thick substance, resembling pisasphaltum, remains in the retort, which may be rendered dry and brittle, like asphaltos, and by a stronger fire is reduced intirely to the carbonaceous state. Alkalies have scarcely any action on petroleum; the vitriolic acid colours, and renders it thick; the nitrous acid inflames it, like essential oils; it readily dissolves sulphur, becomes coloured by metallic calces, and unites, by the assistance of heat, to amber, which it partly softens, and partly dissolves.

The different species of petroleum are used for various purposes in the countries where they are obtained. Kempfer informs us that they are used in Persia for the purpose of illumination, and burned in lamps with a wick; they may likewise be used as fuel. Lehman affirms, that naphta is for this purpose poured on a few handfuls of earth, and afterwards lighted with paper: it immediately catches fire, and burns briskly; but at the same time emits a thick smoke, which sticks to the surrounding bodies, and has a very disagreeable smell: it has been thought that petroleum enters into the composition
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of the Greek fire; the thicker kind is likewise used as mortar for building, for which purpose it is very solid and durable. By decoction of *pisasphaltos* with water, an oil is obtained, which is used instead of tar for vessels.

Lastly, some physicians use petroleum successfully in paralytic weaknesses, and disorders of the muscles, applying it externally to the skin, or exposing the diseased part to its smoke. Van Helmont asserts, that frictions with petroleum are an excellent remedy for frozen limbs, and recommends it as a good preservative against the impression of cold.

S U P P L E M E N T

TO THE ACCOUNT OF THE

M I N E R A L K I N G D O M.

Concerning Mineral Waters, and the Methods of analyzing them.

IN the former part of this work we have treated of all the substances in the mineral kingdom, and have explained their physical properties; we shall conclude the history

history of this kingdom, by treating of mineral waters, because these fluids often hold in solution earthy, saline, and metallic substances, either together or separate. It would have been impossible to have treated with perspicuity and order, respecting them, without first explaining the properties of those substances. Our examination of mineral waters will therefore be more advantageously placed here, as it may serve instead of a recapitulation of the general principles of the chemical analysis applied to minerals.

§ I. Definition and History of Mineral Waters.

Waters, which contain minerals in solution, are distinguished by the appellation of mineral waters. But, as there is no water found in nature, even among those usually reckoned the purest, which is not impregnated by some of these substances, the name of mineral waters ought to be confined to such as are sufficiently impregnated to produce a sensible effect on the animal economy, so as to cure or prevent the disorders to which we are liable.* For this reason,

* It must be observed, that waters which do not contain the principles in sufficient quantity to be rendered sensible by analysis, may nevertheless produce strong effects on the animal economy, nothing more being necessary than that they

reason, the name of medicinal waters seems to be much more applicable to these fluids than that by which they are commonly known, and which is too strongly established to be changed.

The first knowledge of mineral waters, like every other branch of knowledge we possess, was accidentally discovered. The good effects they produced on such as used them, have doubtless been the cause of distinguishing them from common waters. The first philosophers who considered their properties, attended only to their sensible qualities, such as colour, weight, or lightness, smell, and taste. Pliny, however, distinguished a great number of waters, either by their physical properties, or their uses; but the inquiry after methods of ascertaining, by medical processes, the quantity and quality of the principles held in solution by mineral waters, was not attempted till the seventeenth century. Boyle is one of the first who, in the valuable experiments on colours, published by him at Oxford in 1663, mentioned several re-agents capable of indicating the substances dissolved in water, by the alteration produced in their colours. The ac-

they should be very light, brisk, and their temperature above that of common waters: the waters of Plombieres and Luxeuil act in this manner; and differ from the pure water of other springs only in their being of a hotter temperature. Note of the Author.

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demy of sciences, from its first institution, was aware of the importance of analyzing mineral waters; and Duclos, in 1667, attempted the examination of the mineral waters of France: the researches of this chemist may be found in the original Memoirs of this society. Boyle was particularly employed in inquiries respecting mineral waters about the end of the seventeenth century, and published a treatise on this subject in 1685. Boulduc, in the year 1729, published a method of analyzing waters, which is much more perfect than any which were employed before his time: it consists in evaporating these fluids, at different times, and separating, by filtration, the substances which are deposited, in proportion as the evaporation proceeds.

Many celebrated chemists have since made successful experiments on mineral waters, and almost every one made valuable discoveries respecting the different principles contained in these fluids. Boulduc discovered natrum, and determined its properties; Le Roi, physician of Montpellier, discovered calcareous muriate; Margraaf the muriate of magnesia; Priestley cretaceous acid; and Monnet and Bergman the hepatic gas. The two last-mentioned chemists, besides the discoveries with which they have enriched the art of analyzing waters, have published complete treatises on the method of proceeding in

in this analysis; and have carried this part of chemistry to a degree of perfection and accuracy, far exceeding that which it possessed before the time of their labours. We are likewise in possession of particular analyses, made by very good chemists, of a great number of mineral waters, and which serve to throw great light on this inquiry, which, with justice, is esteemed one of the most difficult in the whole art of chemistry. The limits we have prescribed to ourselves do not permit us to enter at large into the history of the analysis of waters, which may be found in many treatises; but we shall not fail to mention the authors of discoveries as occasion may require.

§ II. Principles contained in Mineral Waters.

It is but a few years since the substances capable of remaining in solution in water have been accurately known. This appears to have arisen from the want of accurate chemical methods of ascertaining the nature of these substances; and the certainty of their existence has naturally followed the discovery of methods of ascertaining them. Another cause which has retarded the progress of science in this respect, is, that mineral matters, dissolved in waters, are almost always in very small doses, and are also mixed together in considerable numbers, so that they mutually tend to conceal or alter those

those properties in which their distinctive characters consist. Nevertheless, the numerous experiments of the chemists we have quoted, and a great number of others, which we shall occasionally mention, have shewn, that some mineral substances are often found in waters, others scarcely ever met with; and lastly, many which are never held in solution by that fluid. We shall here consider each class of these substances in order.

Quartzose earth is sometimes suspended in waters; and as it is in a state of extreme division, it remains suspended without precipitating; but its quantity is extremely minute.

Clay likewise appears to exist in water: the extreme subtlety of this earth, by which it is dispersed through the whole mass of water, causes it to render them turbid. Argillaceous waters are whitish, and have a pearl, or opal colour; they are likewise smooth, or greasy to the touch, and have been called saponaceous waters.

Lime, magnesia, and ponderous earth, are never found pure in waters; they are always combined with acids.

Fixed alkalies are never met with in a state of purity in waters, but frequently combined with acids, in the form of neutral salts: the same observation applies to the volatile alkali, and most acids, except the cretaceous acid, which is often free, and in possession of all its properties in waters. It constitutes

constitutes a peculiar class of mineral waters, known by the name of gaseous, spirituous, or acidulous waters.

Among the perfect neutral salts, scarcely any are met with but vitriol of soda or Glauber's salt, the muriates of soda, and of pot-ash, and cretaceous soda, which are frequently dissolved in mineral waters; nitre, and cretaceous tartar, are rarely found.

Selenite, calcareous muriate, chalk, Epsom salt, or vitriol of magnesia, muriate of magnesia, and cretaceous magnesia, are the earthy salts which are most commonly found in waters. As to the calcareous nitre, and nitre of magnesia, which some chemists have asserted they have met with, these salts are scarcely ever found in mineral waters, properly so called, though they exist in salt waters.

The argillaceous neutral salts, and salts with base of ponderous earth, are scarcely ever dissolved in waters. Alum appears to exist in some waters.*

Pure inflammable gas has not yet been found dissolved in mineral waters.

Pure sulphur has not been found in these

* We do not here mention the opinion of le Givre, and other chemists, who consider alum as one of the most usual principles found in mineral waters. But accurate experiments, made by M. Mitouart, have shewn, that the waters of la Dominique de Vals contain alum; and M. Opoix has ascertained the existence of this salt in the waters of Provins.—Note of the Author.

fluids, though it may exist very rarely, in small quantities, in the state of liver of sulphur. Sulphureous waters are most commonly mineralized by the hepatic gas, or vapour of liver of sulphur.

Lastly, among metals, iron is most commonly dissolved in waters, and may be found in two states; either combined with the cretaceous acid, or with the vitriolic acid. Some chemists have supposed that it was likewise dissolved in its metallic state, without an acid intermedium; but as this metal scarcely ever exists in nature, without being either in the state of rust, or of that of vitriol, the opinion of these philosophers could only be maintained at the time when the cretaceous acid was not yet discovered; and the solubility of iron in water, without the assistance of the vitriolic acid, could not otherwise be accounted for. Bergman affirms, that iron, as well as manganese, is found in certain waters, combined with the muriatic acid.

Arsenic, and the vitriols of copper and zink, which exist in many waters, communicate poisonous properties to them, and shew, when discovered by analysis, that the use of such waters must be carefully avoided.

Most chemists, at present, deny the existence of bitumen in waters: in fact, the bitter taste was the cause why waters were formerly supposed to contain these oily substances; but it is now known that this taste, which

which does not exist in bitumen, is produced by the calcareous muriate.

There is no difficulty in conceiving how water, which percolates through the interior parts of the globe, and especially through the mountains, may become charged with the different substances we have enumerated. It is likewise clear, that, according to the nature and extent of the strata of earth, through which they pass, mineral waters will be more or less charged with these principles, and that the quantity and nature of these principles must be subject to great variations.

§ III. The different Classes of Mineral Waters.

It appears from what we have already observed respecting mineral waters, that these fluids may be classed according to the earthy, saline, and metallic substances they hold in solution; and that the number of classes, on this principle, would be very considerable: but it must be observed, that none of these substances are found single and alone in waters; but on the contrary they are often dissolved, in the number of three, four, five, or even more. This circumstance creates a difficulty in the methodical classification of waters, relative to the principles that they contain. However, if we attend to those substances which are the most abundantly contained in waters, or whose properties are

the most prevalent, we shall be able to make a distinction, which, though not very accurate, will be sufficient to arrange these fluids, and to form a judgment of their virtues. Chemists, who have attended to mineral waters in general, have availed themselves of this method. M. Monnet has established three classes of mineral waters; the alkaline, the sulphureous, and the ferruginous: and subsequent discoveries have enlarged the number of classes. M. Duchanoy, who has published a valuable treatise on the art of imitating mineral waters, distinguishes ten, viz. the gaseous, the alkaline, the earthy, the ferruginous, the simple hot, the gaseous thermal, the saponaceous, the sulphureous, the bituminous, and the saline waters. Although it may be urged as a reproach, that this author has made his classes too numerous, since the pure gaseous and bituminous waters are unknown; yet his division is doubtless the most complete, and gives the most accurate idea of the nature of the different mineral waters, and consequently is the best suited to his subject. We shall here propose a division less extensive, and in our opinion more methodical, than that of M. Duchanoy; at the same time observing, that we do not consider simple thermal waters as mineral waters, because they consist merely of heated water, according to the best chemists; and that we shall not speak of bituminous

minous waters, because none such have been yet found.

All mineral waters may be arranged in four classes, viz. acidulous, saline, sulphureous, and ferruginous waters.

CLASS I. Acidulous Waters.

Gaseous waters, which may with more propriety be called acidulous waters, are those in which the cretaceous acid predominates; they are known by their sharp taste, and the facility with which they boil, and afford bubbles by simple agitation: they redden the tincture of turnsole, precipitate lime-water and liver of sulphur. As no waters have yet been discovered which contain this acid pure and alone, we think this class may be divided into several orders, according to the other principles contained in them, or the modifications they exhibit. They all appear to contain more or less alkali and calcareous earth; but their different degrees of heat afford a good criterion for dividing them into two orders; the first might comprehend cold, acidulous, and alkaline waters, such as those of Seltzer, Saint-Myon, Bard, Langeac, Chateldon, Vals, &c.; in the second might be placed, hot, or thermal, acidulous, and alkaline waters, as those of Mount D'or, Vichy, Chatelgyon, &c.

CLASS II. Saline or Salt Waters.

By the name of saline waters, we understand with M. Duchanoy, such as contain a sufficient quantity of neutral salt to act strongly on the animal economy, so as most commonly to purge. The theory and nature of these salts are easily discovered; they perfectly resemble the solutions of salts made in our laboratories; but they almost always contain two or three different species of salts. The vitriol of soda, or Glauber's salt, is very rare; vitriol of magnesia, or Epsom salt, marine salt, or muriate of soda, calcareous and magnesian muriates, are the saline principles which mineralize them, either together or separate. The waters of Sedlitz, of Seydschutz, and of Egra, abound with Epsom salt, frequently mixed with muriate of magnesia. Those of Balaruc contain marine salt, chalk, and the calcareous and magnesian muriates; those of Bourbonne marine salt, selenite, chalk; and those of la Mothe contain marine salt, selenite, chalk, Epsom salt, muriate of magnesia, and an extractive matter. It must be here observed, that salts with base of magnesia, are much more common in waters than has hitherto been supposed; and that few analyses have yet been made, in which they have been well distinguished from calcareous muriate,

CLASS III. Sulphureous Waters.

The name of sulphureous waters has been given to such mineral waters as appear to possess some of the properties of sulphur; such as the smell, and the property of discolouring silver. Chemists have long been ignorant of the true mineralizer of these waters; most have supposed it to be sulphur, but they never succeeded in exhibiting it, or at least have found it in quantities scarcely perceptible. Those who have made experiments on some of these waters, have allowed them to contain either sulphureous spirit or liver of sulphur. Mess. Venel and Monnet, are the first who opposed this opinion; the latter in particular, nearly discovered the truth, when he considered sulphureous waters as impregnated merely by the vapour of liver of sulphur. Rouelle the younger likewise affirmed, that these fluids might be imitated by agitating water in contact with air, disengaged from liver of sulphur by an acid. Bergman carried this doctrine much farther, by examining the properties of hepatic gas, which we have spoken of under the article sulphur: he has proved that this gas mineralizes sulphureous waters, which he therefore calls hepatic waters, and has directed methods of ascertaining the presence of sulphur. Not-

withstanding these discoveries, M. Duchanoy, speaking of sulphureous waters, admits liver of sulphur, sometimes alkaline, sometimes calcareous, or argillaceous. He follows the opinion of Le Roy of Montpellier; who, as we have observed in the history of sulphur, proposed a liver of sulphur with base of magnesia in imitating these waters. It appears in fact to be true, that there are waters which contain a small quantity of liver of sulphur; while there are others, which are mineralized only by hepatic gas. In this case it will be necessary to distinguish sulphureous waters into two orders; the name of hepatic might, perhaps, be given with propriety to such as hold a small quantity of liver of sulphur in solution, and hepaticized to such as are impregnated only with the hepatic gas. The waters of Bareges and Cauterets appear to belong to this first order, and those of St. Amant, Aix la Chapelle, and Montmorency, appear to belong to the second. Most of these waters are thermal; but that of Enghien, near Montmorency, is cold.

CLASS IV. Ferruginous Waters.

Iron being the most abundant of metals, and the most susceptible of alteration, it is not to be wondered at that water easily becomes charged with it, and consequently that the ferruginous waters are the most abundant

abundant and most common of all mineral waters. Modern chemistry has thrown great light on this class of waters; they were formerly supposed to be all vitriolic. M. Monnet has ascertained that most of them do not contain vitriol, and he supposed that the iron is dissolved without the intermedium of an acid. It is at present known, that the iron is not in the state of vitriol, but is dissolved by means of the cretaceous acid, and forms the salt which we have called chalk of iron. Messrs. Lane, Rouelle, Bergman, and many other chemists, have put this out of doubt. The greater or less quantity of cretaceous acid, and the state of the iron in waters of this kind, render it necessary to distinguish the present class into three orders.

The first order comprehends martial acidulous waters, in which the iron is held in solution by the cretaceous acid, whose superabundance renders them brisk and subacid. The waters of Bussang, Spa, Pyrmont, Pouchon, and la Dominique de Vals, are of this first order.

The second contains simple martial waters, in which the iron is dissolved by the cretaceous acid, without excess of the latter. These waters consequently are not acidulous. The water of Forges, Aumale and Conde, as well as the greater number of ferruginous waters, are of this order; this distinction

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of ferruginous waters was made by M. Duchanoy.

But we add a third order, after M. Monnet, which is that of vitriolic waters. Though these are extremely rare, yet some of them are found. M. Monnet has placed the waters of Passy in this order. M. Opoix admits the vitriol of Mars, even in a considerable dose in the waters of Provins. It is true, that M. de Fourcy denies its existence, and considers the iron of these waters as dissolved by fixed air. But no decision can be made respecting this subject, because the results of these chemists intirely disagree, and require new experiments to be made. It must be added, that the iron is not found alone in these waters, but is mixed with chalk, selenite, various muriatic salts, &c. However, as the metal they contain is the principal basis of their properties, they must be called martial, in conformity with the principles we have laid down.*

As to the saponaceous waters admitted by M. Duchanoy, we must wait till chemical and medical experiments have ascertained

* In the enumeration of waters divided into classes, we do not mention those which may contain arsenic and copper, because they are true poisons. We likewise omit such waters as contain volatile alkali, sal-ammoniac, and extractive matters produced by the putrefaction of organic matters on which they have stood. These waters are not medicinal.

the cause of their saponaceous property, which this physician attributes to clay; as well as of the effects they may produce in the animal economy, as medicines, by virtue of this property.

From these details we find, that all mineral and medicinal waters are divided into nine orders, viz.

Cold acidulous waters.

Hot or thermal acidulous waters.

Vitriolic saline waters.

Muriatic saline waters.

Hepatic waters.

Hepatized waters.

Simple martial waters.

Martial and acidulous waters.

Martial vitriolic waters.

§ IV. The Examination of Mineral Waters, according to their Physical Properties.

After having shewn the different matters which may be found in waters, and exhibited a slight sketch of the method in which they may be divided into classes and orders, according to their principles, it will be necessary to mention the methods of analysing them, and discovering with the greatest possible degree of accuracy, the substances they hold in solution. This analysis has been justly considered as the most difficult part of chemistry, since it requires a perfect knowledge of all chemical phenomena, joined to
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the habit of making experiments. To obtain an accurate knowledge of the nature of any water proposed to be examined. 1. The situation of the spring, and the nature of the soil, more especially with respect to mineral strata, must be carefully observed; for this purpose cavities may be dug to different depths, in order to discover by inspection, the substances with which the water may be charged. 2. The physical properties of the water itself, such as its taste, smell, colour, transparence, weight, and temperature, must next be examined; for this purpose, two thermometers which perfectly agree, and a good hydrometer, must be provided. These preliminary experiments require likewise to be made in the different seasons, different times of the day, and especially in different states of the atmosphere; for a continuance of dry weather, or of abundant rain, has a singular influence on waters. These first trials usually shew the class to which the water under examination may be referred, and direct the method of analysis. 3. The depositions formed at the bottom of the basons, the substances which float on the water, and the matters which rise by sublimation, form likewise an object of important research, which must not be neglected. After this preliminary examination, the proper analysis may be proceeded on, which is made after
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three methods ; by re-agents, by distillation, and by evaporation.

§ V. The Examination of Mineral Waters
by Re-agents.

These substances, which are mixed with waters, in order to discover the nature of the bodies held in solution by such waters, from the phenomena they present, are called re-agents.

The best chemists have always considered the use of re-agents as a very uncertain method of discovering the principles of mineral waters. This opinion is founded on the considerations that their effects do not determine in an accurate manner, the nature of the substances held in solution in waters ; that the cause of the changes which happen in fluids by their addition is often unknown : and that in fact, the saline matters usually applied in this analysis, are capable of producing a great number of phenomena respecting which it is often difficult to form any decision. For these reasons, most chemists, who have undertaken this analysis, have placed little dependence on the application of re-agents. They have concluded, that evaporation affords a much surer method of ascertaining the nature and quantity of the principles of mineral waters ; and it is taken for granted, in the best works on the analysis

lysis of these fluids, that re-agents are only to be used as secondary means, which at most serve to indicate or afford a probable guess of the nature of the principles contained in waters ; and for this reason, modern analysts have admitted no more than a certain number of re-agents, and have greatly diminished the list of those used by the earlier chemists.

But it cannot be doubted at present, that the heat required to evaporate the water, however weak it may be, must produce sensible alterations in its principles, and change them in such a manner, as that their residues, examined by the different methods of chemistry, shall afford compounds differing from those which were originally held in solution in the water. The loss of the gaseous substances, which frequently are the principal agents in mineral waters, singularly changes their nature, and besides causes a precipitation of many substances, which owe their solubility to the presence of these volatile matters, and likewise produces a re-action among the other fixed matters, whose properties are accordingly changed. The phenomena of double decompositions, which heat is capable of producing between compounds that remain unchanged in cold water, cannot be estimated and allowed for, but in consequence of a long series of experiments not yet made. Without entering, therefore, more fully into these considerations,

siderations, it will be enough to observe, that this assertion, whose truth is admitted by every chemist, sufficiently shews, that evaporation is not intirely to be depended on. Hence it becomes a question, whether there be any method of ascertaining the peculiar nature of substances dissolved in water without having recourse to heat; and whether the accurate results of the numerous experiments of modern writers afford any process for correcting the error which might arise from evaporation. The following pages extracted from a memoir communicated by myself to the Royal Society of Medicine, will shew, that very pure re-agents used in a peculiar manner, may be of much greater use in the analysis of mineral waters than has hitherto been thought.

Among the considerable number of re-agents proposed for the analysis of mineral waters, those which promise the most useful results are tincture of turnsole, syrup of violets, lime-water, pure and caustic vegetable alkali, caustic volatile alkali, oil of vitriol, nitrous acid, lime-water saturated with the colouring matter of Prussian blue, spiritous tincture of nut-galls, and the nitrous solutions of mercury and of silver. Bergman adds to these, paper coloured by the aqueous tincture of Fernambouc, which becomes blue by alkalis, the aqueous tincture of terra merita, which the same salts convert

vert to a brown red, the acid of sugar to exhibit the smallest possible quantity of lime, and the muriatic salt of ponderous earth to ascertain the smallest quantity of vitriolic acid.

The effects and use of these principal reagents have been explained by all chemists, but they have not insisted on the necessity of their state of purity. Before they are employed, it is of the utmost importance perfectly to ascertain their nature, in order to avoid fallacious effects. Bergman has treated very amply of the alterations they are capable of producing. This celebrated chemist affirms, that paper coloured with the tincture of turnsole becomes of a deeper blue by alkalis; but that it is not altered by the cretaceous acid, which he calls aerial acid. But as this colouring matter is useful chiefly to ascertain the presence of this acid, he directs its tincture in water to be used sufficiently diluted till it has a blue colour. He absolutely rejects syrup of violets, because it is subject to ferment, and because it is scarcely ever obtained without adulteration in Sweden. M. de Morveau adds in a note, that it is easy to distinguish a syrup coloured by turnsole, by the application of corrosive sublimate, which gives it a red colour, while it converts the true syrup of violets to a green.

Lime-water is one of the most useful reagents

agents in the analysis of mineral waters, though few chemists have expressly mentioned it in their works. This fluid decomposes metallic salts, especially martial vitriol, whose iron it precipitates; it separates clay and magnesia from the vitriolic and muriatic acids, to which these substances are frequently united in waters. It likewise indicates the presence of the cretaceous acid, by its precipitation. M. Gioanetti, a physician of Turin, has very ingeniously applied it to ascertain the quantity of cretaceous acid contained in the water of St. Vincent. This chemist, after having observed that the volume or bulk of this acid, from which its quantity has always been estimated, must vary, according to the temperature of the atmosphere, mixed nine parts of lime-water with two parts of the water of St. Vincent; he weighed the calcareous earth formed by the combination of the cretaceous acid of the mineral water with the lime, and found, according to the calculation of Jacquin, who proves the existence of thirteen ounces of this acid in thirty-two ounces of chalk, that the water of St. Vincent contained somewhat more than fifteen grains. But as the lime-water may seize the cretaceous acid united with fixed alkali, as well as that which is at liberty, M. Gioanetti, to ascertain more exactly the quantity of this last, made the

same experiment with water deprived of its disengaged acid by ebullition. This process may therefore be employed to determine, in an easy and accurate manner, the weight of disengaged cretaceous acid, contained in a gaseous mineral water.

One of the principal reasons which have induced chemists to consider the action of re-agents in the analysis of mineral waters as very fallacious, is, that they are capable of indicating several different substances held in solution in waters, and that it is then very difficult to know exactly the effects they will produce. This observation relates more especially to vegetable alkali, considered as a re-agent, because it decomposes all the salts which are formed by the union of acids with clay, magnesia, lime, and metals. When this alkali precipitates a mineral water, it cannot, therefore, be known by simple inspection of the precipitate, of what nature the earthy salt, decomposed in the experiment, may be. Its effect is still more uncertain when the alkali made use of is saturated with cretaceous acid, as is most commonly the case; since the acid to which it is united augments the confusion of effects: for this reason, I propose the use of very pure caustic vegetable alkali, which likewise possesses an advantage over the effervescent alkali, viz. that of indicating the presence of chalk dissolved in a gaseous water, by virtue of the
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the superabundant cretaceous acid; for it seizes this acid, and the chalk falls down of course. I have established this fact, by pouring soap lees newly made, into an artificial gaseous water, which held chalk in solution. The latter substance is precipitated in proportion as the caustic fixed alkali seizes the cretaceous acid which held it in solution. By evaporating the filtrated water to dryness, I have obtained salt of soda, strongly effervescent with spirit of vitriol. The caustic fixed alkali likewise occasions a precipitate in mineral waters, though they may not contain earthy salts; for if they contain an alkaline neutral salt, of a less soluble nature, the additional alkali will precipitate it by uniting with the water, nearly in the same manner as spirit of wine does. M. Gioanetti has observed this phenomenon in the waters of St. Vincent; and it may easily be seen by pouring caustic alkali into a solution of vitriolated tartar, or muriate of soda; these two salts being quickly precipitated.

The caustic volatile alkali is in general less productive of error, when mixed with mineral waters; because it decomposes only earthy salts, with base of clay or magnesia, and does not precipitate the calcareous salts. It is necessary, however, to make two observations respecting this salt: the first is, that it must be exceedingly caustic, or to-

tally deprived of cretaceous acid; without this precaution, it decomposes calcareous salts by double affinity: the second is, that the mixture must not be left exposed to air, when the effect of its action is required to be inspected several hours after it is added; because, as M. Gioanetti has well observed, this salt in a very short time seizes the cretaceous acid of the atmosphere, and becomes capable of decomposing calcareous salts. To put this important fact out of doubt, I made three decisive experiments; some grains of selenite, formed of transparent calcareous spar, and spirit of vitriol, were dissolved in distilled water. It is necessary to make the selenite with transparent spar, because chalk, or Spanish white, contain magnesia and river water. I divided this solution into two parts; into the first I poured a few drops of volatile alkaline spirit, recently made, and very caustic; this I put into a well-closed bottle: at the end of twenty-four and forty-eight hours it was clear and transparent, without any precipitate, and therefore no decomposition had taken place. The second portion was treated in the same manner with the volatile alkaline spirit, but placed in a vessel which communicated with the air by a large aperture: at the end of a few hours a cloud was formed near the upper surface, which continually increased, and

and was at last precipitated to the bottom. This deposition effervesced strongly with spirit of vitriol, and formed selenite. The cretaceous acid contained in this precipitate was therefore afforded by the volatile alkali which had attracted it from the atmosphere. This combination of cretaceous acid and alkaline gas, forms ammoniacal chalk, capable of decomposing calcareous salts by double affinity, as Black, Jacquin, and many other chemists have shewn, and as may be easily proved, by pouring a solution of concrete volatile alkali, or ammoniacal chalk, into a solution of selenite, which is not rendered turbid by the caustic volatile alkali. Lastly, to render the theory of this second experiment clearer, I took the first portion to which the caustic volatile alkali had been added, and which having been kept in a close vessel, had lost no part of its transparency. I reversed the bottle which contained it, over the funnel of a very small pneumato-chemical apparatus, and by the assistance of a syphon, I passed into it cretaceous acid gas disengaged from the effervescent fixed alkali by spirit of vitriol. In proportion as the bubbles of this acid passed through the mixture, it became turbid in the same manner as lime-water: by filtration a precipitate was separated, which was found to be chalk, and the water by evaporation, afforded ammo-

niacal vitriol : gaseous water, or the acid spirit of chalk, produced the same decomposition in another mixture of pure selenite and caustic volatile alkali. This decisive experiment clearly shews, that the volatile alkali decomposes selenite by double affinity, and by means of the cretaceous acid. Hence we see, that when it is required to preserve a mixture of the mineral water with volatile alkali for several hours, (which is sometimes necessary, because it does not decompose certain earthy salts but very slowly) the experiment must be made in a vessel which can be accurately closed, in order to prevent the contact of air, which would falsify the result. This precaution, which is of great importance in the use of all re-agents, is likewise mentioned by Bergman and Gioanetti. To these I shall add another observation concerning the use of volatile alkali. As it is a matter of considerable difficulty to preserve the volatile alkali in the state of perfect causticity, though it is necessary to be had in such a state, for the analysis of mineral waters, a very simple expedient, which I have often used with success, may be applied in this case. It is to pour a small quantity of volatile alkaline spirit into a retort, whose neck is plunged in the mineral water : when the retort is slightly heated, the alkaline gas becomes disengaged, and passes highly caustic

tic into the water. If it occasions a precipitate, it may be concluded that the mineral water contains martial vitriol, which may be known by the colour of the precipitate, or otherwise that it contains salts, with base of aluminous or magnesian earth. It is difficult to determine from the physical properties of the earthy precipitate formed in waters by the caustic volatile alkali, to which of the two last bases it is to be attributed; yet the manner in which it is formed may serve to decide. Six grains of Epsom salt were dissolved in four ounces of distilled water, and six grains of alum in an equal quantity of the same fluid: through each of these solutions a small quantity of alkaline gas was passed: the solution of Epsom salt immediately became turbid, while that of alum did not begin to exhibit a precipitate till twenty minutes after. These mixtures were carefully included in well-closed bottles. The same phenomenon took place with the nitres and muriates of magnesia and aluminous earth, dissolved in equal quantities of distilled water, and treated in the same manner. The quickness or slowness of the precipitation of a mineral water, by the addition of alkaline gas, therefore affords the means of ascertaining the nature of the earthy salt decomposed by this gas. In general, salts with base of magnesia, are much more usually met with

than those with base of aluminous earth. Bergman has observed, that the volatile alkali is capable of forming with vitriol of magnesia or Epsom salt, a compound, in which a portion of this neutral salt is combined, without decomposition, with a portion of ammoniacal vitriol. This non-decomposed portion of Epsom salt, may probably form with the ammoniacal vitriol a mixed neutral salt, similar to sal alembroth. The volatile alkali does not, therefore, precipitate the whole of the magnesia, and consequently does not accurately exhibit the quantity of Epsom salt, of which that earth is the base. For this reason lime-water, in my opinion, is preferable for ascertaining the nature and quantity of salts with base of magnesia contained in mineral waters. It has likewise the property of precipitating the salts with argillaceous base much more abundantly and readily than alkaline gas.*

The concentrated vitriolic acid precipitates a white powder from water which contains ponderous earth, according to Bergman; but, as the same chemist observes,

* It may be observed, that I repeat many facts already explained in the course of this work, which I have thought proper to do, in order to render this small treatise on the analysis of mineral waters more perspicuous and complete, and to collect, in one view, all the knowledge which appears to be indispensably necessary to be possessed by such as undertake this species of analysis.

that

that this earth is seldom found in mineral waters, it will not be necessary to enlarge on the effects of this re-agent. When it produces an effervescence or bubbles in water, it indicates the presence of chalk, cretaceous fixed alkali or pure cretaceous acid: each of these substances may be distinguished by certain peculiar phenomena. If water containing chalk be heated after the addition of the vitriolic acid, a pellicle and deposition of selenite are soon formed, which does not happen with waters which are simply alkaline. At first consideration, it may seem that the selenite ought to be precipitated as soon as the vitriolic acid is poured into water containing chalk; this, however, very seldom happens without the assistance of heat, because these waters most commonly contain a superabundance of cretaceous acid which favours the solution of the selenite, and of which it is necessary to deprive them before the salt can be precipitated. This fact may be shewn, in the clearest manner, by pouring a few drops of concentrated vitriolic acid into a certain quantity of lime-water which has been precipitated, and afterwards rendered clear by the addition of cretaceous acid; if the lime-water be highly charged with regenerated chalk, a precipitate of selenite is thrown down in a few minutes, or more slowly in proportion as the cretaceous acid is set at liberty.

If

If no precipitate be afforded by standing, as will be the case when the quantity of selenite is very small, and the superabundant cretaceous acid considerable, the application of a slight degree of heat will cause a pellicle of selenite, and a precipitate of the same nature to be formed.

The smoking spirit of nitre is recommended by Bergman to precipitate sulphur from hepaticized waters. The experiment may be made by pouring a few drops of the smoking spirit on distilled water, in which the gas disengaged from caustic liver of sulphur, heated in a retort, has been received. This artificial hepatic water, which does not considerably differ from natural sulphureous waters, except in the circumstance of its being more difficult to filter, and its always appearing somewhat turbid, affords a precipitate in a few seconds, by the addition of nitrous acid; the precipitate is of a yellowish white; when collected on a filter and dried, it burns with the flame and smell of sulphur, and in other respects has every character of that inflammable body. The spirit of nitre seems to alter hepatic gas in the same manner as it does all other inflammable substances, by virtue of the great quantity of pure air it contains. Scheele has recommended the dephlogisticated muriatic acid to precipitate the sulphur, from waters of this nature, but it did not produce

duce this effect on the waters of Enghien ; and I have discovered that the sulphureous acid precipitates sulphur with great facility.

There are few re-agents, whose mode of action is less known than that of the phlogisticated alkali ; it has been long since ascertained, that this liquor prepared with bullock's blood, contains Prussian blue ready formed ; it has been thought that this blue might be separated by the addition of an acid ; and in this state it has been proposed as a substance capable of exhibiting iron existing in mineral waters. Whether it be true or not, that the colouring matter of Prussian blue is contained in phlogisticated lixivium, as Bucquet supposed, and Mr. Baunach has since ascertained ; it seems clear that this lixivium ought to be excluded from the class of re-agents. Macquer having discovered that Prussian blue is decomposed by alkalies, proposed the saturated liquor of the colouring matter of this blue, as a test to ascertain the presence of iron in mineral waters. But as the liquor itself likewise contains a small quantity of Prussian blue, which may be separated by means of an acid, as Macquer has shewn, M. Baumé advises that two or three ounces of distilled vinegar be added to each pound of this Prussian alkali, and digested in a gentle heat, till the whole of the Prussian blue is precipitated ; after which pure fixed alkali is to be

be added to saturate the acid of vinegar. Notwithstanding this ingenious process, I have observed, that the Prussian alkali purified by vinegar deposits Prussian blue, in process of time, more especially by evaporation. M. Gioanetti made the same observation by evaporating the Prussian alkali, purified by the method of Baumé, to dryness: he has proposed two processes for obtaining this liquor in a state of purity, and totally exempt from iron; the one consists in supersaturating the Prussian alkali with distilled vinegar, evaporating it to dryness by a gentle heat, dissolving the remaining mass in distilled water, and filtrating the solution; all the Prussian blue remains on the filter, and the liquor, which passes through, contains none at all. The other process consists in neutralizing this alkali with a solution of alum, from which, after filtrating, the vitriolated tartar, is separated by evaporation. These two liquors do not afford a particle of Prussian blue with the pure acids, nor by evaporation to dryness. The lime-water, saturated with the colouring matter of Prussian blue, mentioned by us, in treating on iron, does not require these preliminary operations: when poured on a solution of martial vitriol, it immediately forms pure Prussian blue without any mixture of green. Acids do not precipitate any Prussian blue from this re-agent; it

it therefore does not contain iron, and consequently is preferable to the Prussian alkalies, in the assay of mineral waters. This phenomenon doubtless depends on the action of the lime, which, when dissolved in water, is far from having the same efficacy on iron as alkalies have. This Prussian lime-water seems to be exceedingly well adapted to distinguish martial waters, whether they be gaseous or vitriolic. In fact, the cretaceous gas, which holds iron in solution in waters, being of an acid nature, decomposes Prussian lixiviums by the way of double affinity, as well as martial vitriol. I have tried Prussian lime-water on Spa-waters, and those of Passy, and I immediately obtained a very perceptible blue in the former, and very abundant in the latter. This, therefore, is a liquor very easily prepared, which does not contain the smallest portion of Prussian blue, and is exceedingly well calculated to exhibit the presence of small quantities of iron in waters. It is a kind of neutral salt, formed by the colouring part of the blue and lime. I have observed, in the foregoing part of this work, in treating of iron, that M. Scheele made the same inferences as myself concerning the utility of this proof liquor, which was mentioned by me as early as the year 1780.

Nut-galls, as well as all other rough and astringent vegetables, such as oak-bark, the fruit of the cypress tree, the husks of nuts, &c. have

have the property of precipitating solutions of iron, and exhibiting that metal of different colours, according to its quantity, its state, and that of the water in which it is dissolved. This colour in general is of all shades, from a pale rose to the deepest black. It is well known that the purple colour, assumed by waters, with the tincture of nut-galls, is not a proof that they contain iron in its metallic state, since martial vitriol and iron united to the cretaceous acid, which is called martial chalk, likewise assume a purple colour by the infusion of nut-galls. The differences of colour observed in these precipitations, as M. Duchanoy has well observed in his *Essays on the Art of Imitating Mineral Waters*, depend rather on the quantity of iron, its greater or less degree of adhesion to the water, and the more or less advanced state of decomposition of the solution. We may here take notice, that though this re-agent has been known and employed with success in the analysis of mineral waters since the time that Duclos recommended it in 1667, and though Macquer, Monnet, and the chemists of the academy of Dijon have made a great number of experiments on nut-galls, the nature of the astringent principle is not yet known. We can only conjecture that it is a peculiar acid, since it unites with alkalies, converts blue vegetable colours to a red, decomposes

decomposes liver of sulphur, and combines with metallic calces. Nut-galls in powder, the infusion of this substance in water, made without heat, and the tincture of spirit of wine, are used to ascertain the presence of iron in mineral waters. The tincture is preferred, because it is not subject to become mouldy as the aqueous solution is. It is a singular circumstance, that the distilled products of nut-galls likewise colour martial solutions. The infusions in acids, alkalies, oils, and ether, exhibit the same phenomenon. The iron precipitated by this matter from acids, is in a state little known, and forms a kind of neutral salt, which though very black, is not attracted by the magnet. It dissolves slowly, and without sensible effervescence in acids, but loses these properties by the action of fire, and is then attracted by the magnet. The nut-gall is so efficacious a re-agent, that a single drop of its tincture colours in the space of five minutes, with a purple tinge, three pints of water, which contains only the twenty-fifth part of a grain of martial vitriol.

The two last re-agents we shall propose for the examination of waters, are solutions of silver and of mercury in the nitrous acid. These have usually been employed to exhibit the presence of the vitriolic or muriatic acids in mineral waters; but many other substances, which do not contain the smallest
portion

portion of those, are likewise precipitated by these solutions. The white and heavy striae which the solution of silver exhibits in water, that contains no more than half a grain of marine salt in the pint, ascertains the presence of the marine acid with great certainty and facility; but they do not in the same manner indicate the presence of the vitriolic acid, since, according to Bergman's estimate, at least thirty grains of vitriol of soda must exist in the pint of water, in order to produce an immediate sensible effect. To this we may add, that fixed alkali, chalk, and magnesia, precipitate the nitrous solution of silver in a much more evident manner, and consequently that the precipitation formed in a mineral water by this solution is insufficient to determine with precision, the saline or earthy substances from which it arose.

The solution of mercury by the nitrous acid, is still more productive of error: it not only indicates the presence of vitriolic and muriatic acids in waters, but it is likewise precipitated by the cretaceous fixed alkali, in a yellowish powder, which might be mistaken for an effect of the vitriolic acid. Lime and magnesia produce a precipitate nearly of the same appearance. It has been commonly supposed, that the very abundant white precipitate which it forms in water, is owing to the presence of marine salt;

salt; yet mucilaginous and extractive substances exhibit the same phenomenon, as is now well known to all chemists. Besides, these sources of error and uncertainty, dependant on the property which several substances have, of producing similar precipitates with the nitrous solution of mercury, there are likewise others which depend on the state of this solution itself, and of which it is of the utmost consequence to know, in order to avoid very considerable errors in the analysis of waters. Bergman has mentioned some of the remarkable differences observed in this solution, according to the manner in which it is made, either with or without heat, more particularly with respect to the colour the precipitates it affords by different intermediums; but he does not say a word concerning the property this solution possesses, of being precipitated by distilled water, when it is highly charged with calx of mercury; though M. Monnet mentioned this fact in his treatise on the dissolution of metals. The importance of this subject renders it necessary to enter more fully into the circumstances which attend it. I have made a great number of solutions of mercury, in very pure nitrous acid, with different doses of these two substances, with heat and in the cold, and with acids of very different strengths. These experiments have afforded the following results.

I. Solutions made in the cold, became charged more or less readily with different quantities of mercury, according to the degree of concentration of the nitrous acid; but whatever the quantity of mercury dissolved in the cold by the concentrated acid may be, no part of it will be precipitated by mere water. I have dissolved in the cold two drachms and a half of mercury, in two drachms of smoking spirit of nitre, weighing one ounce, four drachms, and five grains, in a bottle, which contained an ounce of distilled water: the combination took place with the utmost rapidity; very dense nitrous gas escaped, together with aqueous vapours, dissipated by the heat of the mixture, amounting to more than one fourth of the acid. This solution was of a deep green, and very transparent. I poured a few drops into half an ounce of distilled water: some white striz were formed, which were dissolved by agitation, and afforded no precipitate, though it was the most saturated solution I could make in the cold, and presented the greatest degree of commotion, effervescence, and red vapours, during the combination of the mercury and acids. As it had deposited crystals, I added two drachms of distilled water, which dissolved the whole without any appearance of precipitation. With much greater safety therefore may such solutions, as have been made in the cold

cold with common nitrous acid, and half their weight of mercury, be used in the analysis of mineral waters, for they will never afford a precipitate by the addition of mere water.

2. The weakest nitrous acid strongly heated on mercury, will dissolve a larger quantity than the strongest acid in the cold: the solution, which is of a light yellow colour, will appear thick and oily, and will afford by standing, an irregular yellowish mass, which may be changed into a beautiful turbith by the addition of boiling water; this solution poured into distilled water, forms a very abundant precipitate of a yellow colour, similar to turbith. A solution made in the cold, exhibits the same result, if it be strongly heated, so as to disengage a large quantity of nitrous gas. These solutions made with heat, ought therefore to be excluded from the analysis of mineral waters, because they are decomposable by distilled water.

3. The two solutions appear to differ from each other in the quantity of calx of mercury, which is much greater in that which is precipitated by the water, than in that which is not decomposable by that fluid. I have proved this, by evaporating equal quantities of both these solutions in an apothecaries phial, to reduce them into red precipitate, and I obtained one fourth more of this precipitate from the solution, which

is decomposed by water, than from that which is not rendered turbid. The specific gravity likewise appeared to me to be a good method of ascertaining the relative quantities of calx of mercury contained in these different fluids. I compared weights of equal masses of three mercurial nitrous solutions; the one, which was not at all precipitated by distilled water, and was the result of the first mentioned experiment, weighed one ounce, one drachm, and sixty-seven grains in a bottle, which contained exactly an ounce of distilled water. The second solution was made by a very gentle heat, and produced a slight opal colour with distilled water, and scarcely any sensible quantity of precipitate. The same bottle contained one ounce six drachms twenty-four grains. Lastly, a third mercurial solution considerably heated, and which precipitated a true turbith mineral of a dirty yellow, by distilled water, weighed in the same bottle, one ounce, seven drachms, twenty-five grains.* A decisive experiment remained to be made to confirm this opinion still more perfectly: if the solution precipitated by water, owed this property to a quantity of mercurial calx, too large with respect to the acid, it would of course lose that property by the addition of acid; this accord-

* The above weights are French ounces, gros, and grains, and the specific gravities of the three solutions of mercury are respectively 1.24; 1.74; and 1.9; with respect to distilled water taken as unity. T.

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ingly happened. Aqua fortis was poured on a solution which was decomposed by water, and it soon acquired the property of no longer being precipitated, and was absolutely in the same state as that which had been made slowly at first, by the mere heat of the atmosphere. M. Monnet has mentioned this process, as a means of preventing crystals of mercurial nitre from becoming converted into turbith by the contact of the air. It is by a contrary process, and by evaporating a portion of the acid of a good solution, which is not precipitated by water, that it is converted into a solution much more strongly charged with mercurial calx, and consequently capable of being decomposed by water; its original property may be restored by the addition of a quantity of acid, equal to that which it lost by evaporation.

Such are the different considerations which I have thought it necessary to exhibit, that the effects of re-agents on waters may be better ascertained; but whatever may be the degree of precision to which researches of this nature may be carried; however extensive the knowledge we may have acquired concerning the degrees of purity, and the different states of such substances as are combined with mineral waters, for the purpose of discovering their principles, if it still remains a fact that each of these re-agents is capable of indicating two or three different substances dissolved in these waters, the re-

sult of their action will always be subject to uncertainty. Lime, for example, seizes the cretaceous acid, and precipitates salts with the base of clay, and of magnesia, as well as the metallic salts. Volatile alkali produces the same effect. Fixed alkalies, besides the above-mentioned salts, precipitate those with base of lime. Lime-water charged with the colouring matter of Prussian blue, Prussian alkali, and the spirituous tincture of nut-galls, precipitate martial vitriol and martial chalk. The nitrous solutions of silver and of mercury, decompose all the vitriolic and muriatic salts, which may be various both in quantity and in kind, in the same water, and are themselves decomposable by alkalies, chalk, and magnesia. Among this great number of complicated effects, how shall we distinguish that which takes place in the water under examination, or by what means shall we ascertain whether it is simple or compounded?

These questions, though very difficult, for the time when the expedients of chemistry were little known, are nevertheless capable of being discussed in the present state of our knowledge. I must first observe, that the nature of re-agents being much better known at present than it was some years ago, and their re-action on the principles of water better ascertained, it may, therefore, be strongly presumed that their application may be

be much more advantageously made than has hitherto been supposed: nevertheless, among the great number of excellent chemists who have attended to the analysis of waters, Messrs. Baumé, Bergman, and Gioanetti, are almost the only persons who have been aware of this great advantage. We have been long in the habit of examining mineral waters by re-agents, in very small doses, and often in glasses: the phenomena of the precipitations observed have been noted down, and the experiment carried no further. M. Baumé advises, in his chemistry, that a considerable quantity of the mineral water, under examination, should be saturated with fixed alkalies and with acids, that the precipitates be collected, and their nature examined. Bergman apprehended that the quantity of the principles contained in waters might be judged of from the weight of the precipitates obtained in these mixtures. Several other chemists have likewise employed this method, but always with a view to certain particular circumstances; and no one has hitherto proposed to make a connected analysis of mineral waters by this means. To succeed in this analysis, I think it would be proper to mix several pounds of the mineral water with each re-agent, till the latter ceases to produce any precipitate; the precipitate should then be suffered to subside during the time

of twenty-four hours, in a vessel accurately closed; after which the mixture being filtered, and the precipitate dried and weighed, the operator may proceed to examine it by the known methods. In this manner the nature of the substance will be clearly ascertained, on which the re-agent has acted, and the cause of the decomposition may consequently be inferred. A certain order may be followed in these operations, by mixing the waters first with such substances as are least capable of altering them, and afterwards passing to other substances capable of producing changes more varied and difficult to explain. The following method is that which I commonly use in this kind of analysis. After having examined the taste, the colour, the weight, and all the other physical properties of a mineral water, I pour four pounds of lime-water on an equal quantity of the fluid; if no precipitate is made in twenty-four hours, I am sure that the water contains neither the cretaceous acid at liberty, nor the cretaceous fixed alkali, nor earthy salts with the base of aluminous earth or magnesia, nor metallic salts. But if a precipitate be formed, I filter the mixture, and examine the chemical properties of the deposited substance; if it has no taste, if it be insoluble in water, or effervesces with acids, or forms an insipid and almost insoluble salt by the addition of vitriolic acid, I conclude that it is chalk,
and

and that the lime-water has acted only on the cretaceous acid dissolved in the water. If, on the contrary, it is small in quantity, and subsides very slowly; if it do not effervesce, and affords with the vitriolic acid a styptic salt, or a bitter and very soluble salt, it is formed by magnesia or aluminous earth, and often by both. I need not enter at large into the means of distinguishing these two substances from each other, as they are sufficiently explained in the foregoing part of this work. I shall only add, that a sufficient number of experiments ought to be made, to leave no doubt respecting their nature.

After the examination by lime-water, I pour on four other pounds of the same mineral water, a drachm or two of volatile alkaline spirit, perfectly caustic, or I cause alkaline gas, disengaged by heat from the spirit, to pass into the water. When the water is saturated, I leave it at rest in a close vessel for twenty-four hours; if a precipitate be afforded, it can only consist of martial or magnesian, or aluminous salts, whose nature I examine by the different methods mentioned in the foregoing paragraph. But the action of alkaline gas being more fallacious than that of lime-water, which produces the same decompositions, it must be observed that this last should only be used as an assistant means, which does not afford results
equally

equally accurate with those produced by the former re-agent.

When salts with base of aluminous earth, or magnesia, have been discovered by lime-water, or by alkaline gas, the caustic mineral alkali may be used, to distinguish those with base of lime, such as selenite and calcareous marine salt: for this purpose I precipitate some pounds of the water, which I examine by this alkaline liquor, till it no longer produces any turbidness. As this alkali decomposes salts with base of aluminous earth, as well as those composed of lime: if the precipitate resembles in its form, colour, and quantity, that which lime-water has afforded, it may be presumed that the water does not contain calcareous salt, and the chemical examination of the precipitate usually confirms this suspicion; but if the mixture is much more turbid than that made with lime-water; if the deposition be much heavier, more abundant, and more readily afforded, the lime is mixed with magnesia or aluminous earth. I ascertain this by treating the precipitate after the different methods before explained. It may easily be concluded, that iron precipitated by re-agents, at the same time as the salino-terrestrial substances, is easily known by its colour and its taste; and that the small quantity of this metal separated in these processes, is not sufficient to affect the results.

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It were useless to explain at large, the effects of oil of vitriol, spirit of nitre, nutgalls, alkali, or lime saturated with the colouring matter of Prussian blue, employed in reagents or mineral waters. The general account of these effects given in this appendix may suffice; I shall therefore only add, that when they are mixed in large doses with these waters, and the precipitates collected, the nature and quantity of their principles, may be more accurately ascertained, as has been done by Messrs. Bergman and Gioanetti.

Neither shall I dwell on the products which the nitrous solutions of silver or mercury afford when mixed with mineral waters. It is more particularly necessary to operate with large quantities of water, when these reagents are used, in order to determine the nature of the acids contained in the waters. The analysis of these fluids will be complete when their acids are known, because these are often combined with the bases exhibited by the reagents before-mentioned. The colour, the form, and the abundance of the precipitates afforded by the nitrous solutions of mercury and silver, have hitherto exhibited to chemists the nature of the acids which caused them. A thick and ponderous deposition immediately formed by these solutions, denotes the muriatic acid: if it is small in quantity, white, and crystallized with the nitre of silver, or yellowish, and yellow

yellow and irregular when formed with that of mercury, and if it subside but slowly, it is attributed to the vitriolic acid. But, as these two acids are often met with in the same water, and as alkali and chalk likewise decompose the solutions, the results or deductions made from the physical properties of the precipitates must be uncertain. It is therefore necessary to examine them more effectually; for this purpose, lunar, or mercurial solutions may be mixed with five or six pounds of the water intended to be analyzed. The mixtures being filtered, twenty-four hours after, the precipitates must be dried, and treated according to the methods of chemistry. If the precipitate afforded by the nitrous solution of mercury be heated in a retort, the portion of metal united with the muriatic acid of the waters will be volatilized into mercurius dulcis, and that which is combined with the vitriolic acid will remain at the bottom of the vessel, and exhibit a reddish colour. These two salts may likewise be distinguished by putting them on a hot coal: the vitriol of mercury, if present, emits a sulphureous acid, and assumes a red colour; the mercurial muriate remains white, and is volatilized without exhibiting any smell of sulphur. These phenomena likewise serve to distinguish the precipitates which may be formed by the alkaline substances contained in water, since the latter do not emit the sulphureous

fulphureous smell, and are not volatile without decomposition.

The precipitates produced by the combination of mineral waters with the nitrous solution of silver, may be as easily examined as the foregoing. Vitriol of silver being more soluble than lunar cornea, distilled water may be successfully used to separate these two salts. Luna cornea is known by its fixity, its fusibility, and especially in its being less easily decomposable than vitriol of silver. This last, placed on hot coals, emits a sulphureous smell, and leaves a calx of silver, which may be fused without addition. I do not here speak of all the processes chemistry affords for separating or distinguishing the two lunar salts here mentioned; it is sufficient that I have pointed out some of them.

§ VI. The Examination of the Mineral Waters by Distillation.

Distillation is used in the analysis of waters, to ascertain the gaseous substances they may be united to. These substances are either air, more or less pure, or cretaceous acid, or hepatic gas. To ascertain their nature and quantity, some pounds of the mineral water must be poured into a retort, sufficiently large to contain it, without being filled more than half or two-thirds of its capacity;

capacity; to this vessel a recurved tube is to be adapted, which passes beneath an inverted vessel filled with mercury. In this disposition of the apparatus, the retort must be heated till the water perfectly boils, or till no more elastic fluid passes over. When the operation is finished, the quantity of air contained in the empty space of the retort must be subtracted from the bulk of the gas obtained; the rest consists of aeriform fluid, which was contained in the mineral water, whose properties may quickly be known by the proofs of a lighted taper, tincture of turnsole, and lime-water; if it catches fire, and has a fetid smell, it is hepatic gas; if it extinguishes the taper, reddens turnsole, and precipitates lime-water, it is the cretaceous acid; lastly, if it maintains combustion without taking fire, is without smell, and alters neither turnsole nor lime-water, it is atmospheric air. It may happen that the elastic fluid may be purer than the air of the atmosphere: in this case its degree of purity may be judged by the manner in which it maintains combustion, or by mixing it with nitrous or inflammable gas, in the eudiometers of Fontana and Volta. The process used in obtaining gaseous matters, contained in lime-water, is intirely modern. A moistened bladder was formerly used, which was adapted to the neck of a bottle filled with mineral water;

water; the fluid was agitated, and by the swelling of the bladder, an estimate was made of the quantity of gas contained in the water. This method is now known to be fallacious, because water cannot give out all its gas but by ebullition, and because the sides of the moistened bladder alter and decompose the elastic fluid obtained. It is scarcely necessary to remark, that the phenomena exhibited by the water, during the escape of the gas, must be carefully examined, and that a less quantity of water may be exposed to distillation, in proportion as its taste and sparkling indicate that it contains a larger quantity of gas.

Such is the method recommended by modern chemists to obtain the elastic fluids combined with waters. I must observe, 1. That this process cannot be depended on, with regard to acidulous waters, unless the pressure of the atmosphere, and the state of compression of the elastic fluid under the glass vessels, be very accurately accounted for; and as this is not easily done, the absorption of cretaceous acid by lime-water, proposed by M. Gioanetti, appears to be preferable. 2. Though it has been recommended by Bergman to obtain hepatic gas from sulphureous waters, it does not answer, because the heat of ebullition decomposes the gas, and it is likewise decomposed by the mercury, which is converted

verted into ethiops, as soon as it comes in contact with this elastic fluid: for this reason, in my analysis of the waters of Enguien, near Montmorency, I have proposed litharge to absorb this gas in the cold, and to deprive hepatized waters of their sulphur.

§ VII. The Examination of Mineral Waters by Evaporation.

Evaporation is generally considered as the most certain method of obtaining all the principles of mineral waters. We have before observed, and here repeat, that the experiments of Messrs. Venel and Cornette shew that long continued ebullition may decompose saline matters dissolved in water, and for that reason we have advised the examination of them by re-agents, employed in greater proportions: yet evaporation may afford much information, when used, together with the analysis by re-agents, which ought always to be considered as one of the principal methods of examining waters.

The intention of evaporation being to collect the fixed principles contained in a mineral water, it is obvious, that in order to know the nature and proportion of these principles, a considerable quantity of the water must be evaporated, and so much the more, in proportion as the principles

ciples appear to exist in smaller quantities. When the water is thought to contain a large quantity of saline matter, about twenty pounds must be evaporated; if, on the contrary, it appears to hold but a very small quantity in solution, it will be necessary to evaporate a much larger quantity. It is sometimes requisite to perform this operation with several hundred pounds. The nature and form of the vessels, in which waters are exposed for evaporation, is not a matter of indifference. Those of metal, excepting silver, are altered by water; vessels of glass, of a certain magnitude, are very subject to be broken; but those of glazed, smooth pottery, are the most convenient, though the cracks in the glaze sometimes cause an absorption of saline matter; vessels of unglazed porcelain, called biscuit, would doubtless be the most convenient, but their price is a considerable obstacle. Chemists have proposed different methods of evaporating mineral waters; some have directed distillation to dryness, in close vessels, in order to prevent foreign substances, which float in the atmosphere, from mixing with the residue; but this method is excessively tedious: others have advised evaporation by a gentle heat, never carried to ebullition, because they supposed that this last heat alters the fixed principles, and carries up a portion of them. This was the opinion of Venell and Bergman.

M. Monnet, on the contrary, directs the water to be boiled, because this motion prevents the reception of foreign matters contained in the atmosphere. Bergman avoids this inconvenience, by directing the vessel to be covered, and a hole left in the middle of the cover for the vapours to pass out: this last method greatly retards the evaporation, because it diminishes the surface of the fluid. At the commencement, the heat used must be sufficient to repel the dust; but the greatest difference in the manipulation of this experiment, consists in some writers directing, that the substances deposited should be separated, as the evaporation proceeds, in order to obtain each pure and by itself; others, on the contrary direct the operation to be carried on to dryness. We are of the opinion of Bergman, that this last method is the most expeditious and certain; because, notwithstanding the care which may be taken, in the first method, to separate the different substances, which are deposited or crystallized, they are never obtained pure, and must always be examined by a subsequent analysis; and the method is besides inaccurate, on account of the frequent filtrations, and the loss it occasions. Lastly, it is very embarrassing, and renders the evaporation much longer. Mineral waters may therefore be evaporated to dryness, in open glass vessels, on the water-bath, or still more advantageously

advantageously in glass retorts, on a sand-bath.

Various phenomena are observed during this evaporation; if the water be acidulous, it emits bubbles, as soon as the heat first begins to act; in proportion as the cretaceous acid is disengaged, a pellicle is formed, with a deposition of calcareous earth, or martial chalk. These first pellicles are succeeded by the crystallization of selenite; and lastly, the muriatic salts of pot-ash and soda crystallize in cubes at the surface, but the deliquescent are not obtained but by evaporation to dryness.

The residue must then be weighed, and put into a small phial, with three or four times its weight of spirit of wine: the whole being agitated, and suffered to subside for some hours, must be filtered, and the spirit of wine preserved separate. The residue, on which the spirit has not acted, must be dried in a gentle heat, or in the open air; when perfectly dry, it must be weighed, and the loss of weight will shew what quantity of calcareous or magnesian muriate was contained, because these salts are very soluble in spirit of wine. We shall presently speak of the method of ascertaining the presence of these two salts in the spirituous fluid.

The residue, after treatment with spirit of wine, and drying, must be agitated with eight times its weight of cold distilled water,

and filtered. After some hours standing, the residue is to be dried a second time, and boiled half an hour in four or five hundred times its weight of distilled water: this last residue, after filtration, consists of that which cold and boiling water is insufficient to dissolve. The first water contains neutral salts, such as vitriol of soda, or of magnesia; the muriate of soda, or the vegetable alkali and the fixed alkalies, especially mineral alkali, united with cretaceous acid: the large quantity of boiling water scarcely contains any substance but selenite. There are therefore four substances to be examined, after these different operations on the matter obtained by evaporation. 1. The residue insoluble in spirit of wine, and in water of different temperatures. 2. The salts dissolved in spirit of wine. 3. The salts dissolved in cold water. 4, and lastly, Those dissolved in boiling water. We shall now proceed to the experiments necessary to ascertain the nature of these different substances.

1. The residue which has resisted the action of the spirit of wine and water, may be composed of calcareous earth, of magnesian and martial chalk, of clay and of quartz. These two last substances are seldom found in waters, but the three first are very common; the brown, or more or less deep yellow colour, indicates the presence of iron. If the residue be of a white grey, it does not contain

contain this metal. When iron is present, Bergman directs it to be moistened, and exposed to the air till it rusts; in which state vinegar does not act on it. In order to explain the methods of separating these different substances, we will suppose an insoluble residue to consist of the five substances here mentioned; it must first be moistened, and exposed to the rays of the sun; and when the iron is perfectly rusted, the residue must be digested in distilled vinegar. This acid dissolves the lime and magnesia, and by evaporation affords the calcareous acetous salt, distinguishable from the acetous salt of magnesia, by its not attracting the humidity of the air. They may consequently be separated by deliquescence, or by pouring vitriolic acid into their solution. The latter forms selenite, which precipitates; but if the magnesian acetous salt be present, the Epsom salt, composed of magnesia united with the vitriolic acid, will remain in solution, and may be obtained by a well-conducted evaporation. To ascertain the quantity of magnesian and calcareous earths contained in this residue, the selenite is first to be precipitated; and the Epsom salt, formed by the vitriolic acid poured into the acetous solution, must then be precipitated by cretaceous vegetable alkali. The quantities of these precipitates are known by weighing. When the chalk and magnesia of the residue are thus separated, the
iron,

iron, the clay, and the quartz remain. The iron and clay are dissolved by pure muriatic acid, from which the former is precipitated from Prussian lime, and the latter by cretaceous vegetable alkali. These precipitates must likewise be weighed. The matter which remains after the separation of the clay and iron is usually quartzose: its quantity may be known by weighing, and its habitudes by fusion with the blow-pipe with cretaceous mineral alkali. Such are the most accurate processes, recommended by Bergman, for examining the insoluble residue of waters.

2. The spirit of wine used in washing the solid residue of mineral waters, must be evaporated to dryness. Bergman advises treating it with spirit of vitriol, in the same manner as the acetous solution before spoken of; but it must be observed, that this process serves only to exhibit the bases of these salts. To determine the acid, which is ordinarily united with magnesia or lime, and sometimes with both, a few drops of oil of vitriol must be poured on, which excites an effervescence, and disengages the muriatic acid, known by its smell and white vapour when the salt under examination contains that acid. This may likewise be known by dissolving the whole residue in water, and adding a few drops of the solution of silver. The nature of the base, which, as we have observed,

observed, is either lime, magnesia, or both together, is known by the same vitriolic acid, by a similar process with that already explained respecting the acetous solution.

3. The water used in washing the first residue of the mineral water, performed as before directed, with eight times its weight of cold distilled water, contains neutral alkaline salts, such as vitriol of soda, or Glauber's salt, or muriates or marine salts, chalk of pot-ash, and of soda, and vitriol of magnesia: a small quantity of martial vitriol is sometimes found. These salts never exist all together in waters: the vitriol of soda, and the chalk of pot-ash, are very seldom found; but marine salt is frequently met with, together with cretaceous soda. The vitriol of magnesia is likewise frequently met with, and some waters even contain it in considerable quantities. When the first washing of the residue of a mineral water contains only one kind of neutral salt, it may easily be obtained by crystallization; and its nature ascertained from its form, taste, and the action of fire as well as that of the re-agents: but this case is very rare, for it is much more usual to find many salts united in this lixivium. They must therefore be separated, if practicable, by slow evaporation; but as this method does not always perfectly succeed, however carefully the evaporation be conducted, it will be necessary

cessary to re-examine the salts obtained at the different periods of the evaporation. Cretaceous soda is usually deposited confusedly with the muriatic salts, but they may be separated by a process, pointed out by M. Gioanetti. It consists in washing this mixed salt with distilled vinegar; for this acid dissolves cretaceous soda. The mixture must then be dried and washed a second time with spirit of wine, which takes up acetous soda, without acting on marine salt. The spiritous solution being evaporated to dryness, and the residue calcined, the vinegar becomes decomposed and burns. Soda alone remains, whose quantity may be then accurately determined.

4. The water used in the quantity of four or five hundred times the weight of the residuum of the mineral water contains only vitriol of lime, or selenite. This may be ascertained by pure caustic volatile alkali, which occasions no change, while the caustic vegetable alkali precipitates it abundantly. By evaporation to dryness, the quantity of earthy salt contained in the water may be accurately ascertained.

§ VIII. Concerning Artificial Mineral Waters.

The numerous processes we have described for examining the residues of mineral waters by

by evaporation, serve to ascertain with the greatest precision all the several matters held in solution in these fluids. Another process remains to be made to prove the success of the analysis, viz. That of imitating nature in the way of synthesis, by dissolving pure water the different substances, obtained by the analysis of a mineral water which has been examined. If the artificial mineral water has the same taste, the same weight, and exhibits the same phenomena with reagents as the natural mineral water, it is the most complete, and the most certain proof that the analysis has been well made. This artificial combination has likewise the advantage of being procured in all places at pleasure, and at a trifling expence; and is even in some cases superior to the natural mineral waters, whose properties may be changed by carriage, and other circumstances. The most celebrated chemists are of opinion, that it is possible to imitate mineral waters. Macquer has observed, that since the discovery of the cretaceous acid, and the property it is found to possess of rendering many substances soluble in water, it is much more easy to prepare artificial mineral waters. Bergman has described the method of composing waters, which perfectly imitate those of Spa, Seltzer, Pyrmont, &c. He likewise informs us, that they are used with great success in Sweden,

and that he himself has experienced their good effects. M. Duchanoy has published a work, in which he has given a number of processes for imitating all the mineral waters usually employed in medicine. We may therefore hope, that chemistry may render the most essential service to the art of healing, by affording valuable medicines, whose activity may be increased or diminished at pleasure.



END OF VOLUME THE THIRD.

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